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ABSTRACT

This bibliography contains some 2,000 articles on empirical investigation and theoretical considerations covering the topic of students' conceptions entered before September 1990. Publications in journals, books, working papers, and contributions to conferences are included. English, German, and French publications, and ones in other languages are contained in the bibliography. The bibliography is divided into nine groups: (1) general considerations concerning research in this area; (2) everyday notions and scientific notions; (3) development of notions in the history of science as compared to development of notions of individuals; (4) language and notions; (5) methods of investigations; (6) investigations of students' notions; (7) instruction taking students' notions into account; (8) investigations of teachers notions; and (9) notions and teacher training. The entries include the author's name, year of publication, title, place of publication, and a set of keywords that help the reader to categorize the articles. Keywords indicate the group of the article (1-9), physics, chemistry, or biology, and further areas or concepts. Articles dealing with conceptions of the teaching and learning process, conceptions of science, conceptions on the use of science for technology and society, and empirical studies in which gender differences are investigated are also indicated by keywords. An author index, an appendix that contains publications added during the preparation of the present edition from October to December 1990, a second appendix that contains entries from another bibliography not listed in this bibliography, and a list of keywords are included. (KR)

Institute for Science Education
Institut für die Pädagogik der Naturwissenschaften

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Bibliography
Students' Alternative Frameworks and Science Education

Bibliographie
Alltagsvorstellungen und naturwissenschaftlicher Unterricht

3rd Edition · 3. Auflage

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IPN
INSTITUTE FOR SCIENCE EDUCATION
INSTITUT FÜR DIE PÄDAGOGIK DER NATURWISSENSCHAFTEN
AN DER UNIVERSITÄT KIEL

1991 · Institut für die Pädagogik der Naturwissenschaften
an der Universität Kiel
(Institute for Science Education)
Olshausenstraße 62
D-2300 Kiel 1
Federal Republic of Germany

VORWORT

Das Forschungsgebiet, das sich mit "Schülervorstellungen" und ihrer Rolle für den naturwissenschaftlichen Unterricht befaßt, zählt nach wie vor zu den aktivsten im Bereich naturwissenschaftsdidaktischer Forschung. Die erste Auflage der Bibliographie "Alltagsvorstellungen und naturwissenschaftlicher Unterricht" (1985) enthielt etwa 700 Einträge, bei der zweiten Auflage (1988) waren es bereits doppelt so viele, die vorliegende dritte Auflage enthält über 2.000.

Der Titel der Bibliographie "Alltagsvorstellungen und naturwissenschaftlicher Unterricht" erklärt sich aus der Geschichte des Arbeitsgebietes. Er ist heute nur noch bedingt zutreffend. Zwar beschäftigen sich nach wie vor die meisten Arbeiten mit der Untersuchung von Schülervorstellungen zu Phänomenen, Begriffen und Prinzipien, von denen im naturwissenschaftlichen Unterricht die Rede ist. Viele dieser Vorstellungen sind Alltagsvorstellungen, d. h. sie beruhen auf Alltagserfahrungen im Umgang mit Phänomenen und auf alltäglichen Spracherfahrungen. Aber es werden auch zunehmend Vorstellungen allgemeinerer Art (z. B. zur Natur und Reichweite naturwissenschaftlichen Wissens oder zum Lernprozeß) in die Analyse von Lernschwierigkeiten und in die Entwicklung von neuen Unterrichtsansätzen zu ihrer Überwindung einbezogen. Die konstruktivistische Sichtweise ist die Klammer, die diese unterschiedlichen Vorstellungen verbindet. Es wird auch die Beschränkung auf Schülervorstellungen aufgegeben. Die Rolle von Lehrervorstellungen (ganz allgemeiner Art) wird zunehmend als eine Ursache vieler Lernschwierigkeiten erkannt.

Die Bibliographie basiert auf einer Literatursammlung, die Helga Pfundt vor etwa 15 Jahren begonnen hatte. Sie wird seit ihrem frühen Tod im Oktober 1984 von mir fortgeführt. Ich bemühe mich, in der Bibliographie die wichtigsten empirischen Untersuchungen und theoretischen Ansätze zu diskutieren, die im Gebiet der empirischen "konstruktivistisch" orientierten Naturwissenschaftsdidaktik publiziert werden. Dies schließt "offizielle" Publikationen und "graue" Materialien ein. Ich sehe die wichtigsten deutsch- und englischsprachigen Fachzeitschriften systematisch durch. Darüber hinaus versuche ich Tagungsbände, Bücher und dergleichen möglichst umfassend auszuwerten und in Tagungsprogrammen Beiträge zum Thema zu finden. Eine weitere wichtige Informationsquelle sind die Newsletter zweier informeller Zusammenschlüsse von Forschern auf dem hier dokumentierten Gebiet (siehe dazu S. xvii). Viele Kollegen schicken mir von sich aus ihre neuen Arbeiten zu. Ihnen sei herzlich gedankt.

Es gibt eine Reihe weiterer Bibliographien zum Thema der hier vorliegenden (s. S. xvii). Ich habe die dort aufgeführten Publikationen nach Möglichkeit in die vorliegende Bibliographie (bzw. in die Anhänge 1 und 2) aufgenommen.

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Ich schulde Dank vielen Kollegen im IPN. Werner Dierks hat mich mit Informationen vor allem zu Artikeln aus dem Bereich der Chemie versorgt. Hans-Jürgen Waldow hat es ermöglicht Daten, die bislang auf einem größeren Computer gespeichert waren, auf meinen PC zu übertragen. Hans Dörr und Renate Meyer haben die bisherigen Auflagen betreut und die Eingaben der bis dahin aufgelaufenen Artikel übernommen. Martin Vaterodt hat dies für die vorliegende Auflage besorgt. Er hat dabei auch viele Fehler beseitigt, die in den beiden vorangegangenen Auflagen noch vorhanden waren. Ohne seine sorgfältige Arbeit wäre die dritte Auflage nicht zustande gekommen.

Reinders Duit, Dezember 1990

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FOREWORD

Research on "Students' alternative frameworks" is still flourishing. The first edition of the bibliography (1985) contained some 700 quotations, the second edition (1988) some 1400, and the present third edition arrived at more than 2000.

It has become somewhat misleading to indicate the research field presented in the bibliography using labels like "Students' alternative frameworks". The term alternative framework coined by Driver & Easley (cf. gl, p. 8) originally focused on students' alternative conceptions (as, opposed to science conceptions) of phenomena concepts and principles taught in science instruction, i.e. on conceptions at the content level. There are currently strong trends in the direction of considering "alternative frameworks" of a much broader kind (e.g. including conceptions of the nature and range of science, conceptions of the learning process, and teachers' conceptions of various kinds). This research is carried out within what is called the constructivist view. The bibliography may therefore now be viewed as an attempt to document constructivist research in science education.

The bibliography is based on a collection of papers Helga Pfundt started some fifteen years ago. Sadly Helga Pfundt died in October 1984. Since then I have taken care of the bibliography. I include articles on empirical investigations and theoretical considerations. Both publications in journals, books and the like and working papers, contributions to conferences etc. I analyze the leading English and German journals in the field of science education, books in our area and conference programs. Publications in other languages are also contained in the bibliography, especially publications in French, but they are more incidental. Other important sources of information are the newsletters of two informal groups of researchers in our field (cf. p. xvii). Further, many colleagues have been so kind as to send their recent articles and papers. I am most grateful for their help.

There are some other bibliographies on research on students' conceptions available (cf. p. xvii). As far as possible I have included quotations from them in the present third edition of my bibliography.

Many people were involved in work on the bibliography. Werner Dierks provided me with information mainly on research in the field of chemistry. Hans-Jürgen Waldow made it possible to transfer the data which had so far been stored on a main frame computer to a PC. Hans Dörr and Renate Mayer were responsible for the first and second edition of the bibliography. Martin Vaterodt was responsible for the third edition. Not only did he carefully deal with new contributions, he also removed many mistakes that had survived in the first and second editions during the past few years. Without his careful work there would not be a third edition.

Reinders Duit, December 1990

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Reinders Duit: EINFÜHRUNG

(1) ZUM UMGANG MIT DER BIBLIOGRAPHIE

Zu den Zielen der Literatursammlung

Dem Forschungsgebiet "Alltagsvorstellungen und naturwissenschaftlicher Unterricht" wird seit etwa der Mitte der 70er Jahre große Aufmerksamkeit gewidmet. Wir haben die Literatursammlung, die der vorliegenden Bibliographie zugrunde liegt, ursprünglich angelegt, um einen Überblick über das Forschungsfeld zu bekommen, d. h. um uns dort einzuarbeiten. Im Laufe der Zeit hat sich die heutige Literatursammlung ergeben. Sie hilft uns, einen Überblick über die immer noch schnell wachsende Zahl von Forschungsarbeiten zu behalten. Durch die Publikation der vorliegenden Bibliographie hoffen wir, interessierten Kollegen ebenfalls einen Überblick zu ermöglichen. Mit dieser Publikation verbinden wir die folgende Bitte:

Bitte schicken Sie uns Ihren neuen Artikel oder Arbeiten, die wir bislang noch nicht aufgenommen haben, insbesondere dann, wenn es sich um Arbeiten handelt, die nicht in leicht zugänglichen Publikationen (wie Zeitschriften, Sammelbänden und dergleichen) erschienen sind. Wir werden die Beiträge aufnehmen und in einer Ergänzungsliste oder einer Neuauflage berücksichtigen.

Leider müssen wir den folgenden Hinweis geben:

Zwar steht unsere Literatursammlung allen Kollegen offen, die uns am IPN besuchen. Es ist uns aber nicht möglich, Kopien von Publikationen anzufertigen, die in unserer Liste genannt sind. Bitte wenden Sie sich diesbezüglich immer an die Autoren!

Zu den Schwerpunkten der Bibliographie

Der Schwerpunkt der Bibliographie liegt auf den naturwissenschaftlichen Fächern Biologie, Chemie und Physik. Da im angelsächsischen Bereich auch "earth science" zu "science" zählt, enthält die Bibliographie auch Arbeiten dieser Ausrichtung. Sie werden aber nicht gesondert ausgewiesen. Sie finden sich jeweils in den Gruppen g6, g7 und g8 unter "Sonstige". Untersuchungen zu "Vor-

stellungen" und ihrer Bedeutung für den Lernprozeß gibt es auch in anderen Fächern. Insbesondere die Mathematik ist dabei zu erwähnen. Die folgenden Tagungsbände geben einen ersten orientierenden Überblick:

Archenhold, W. F., Orton, A., Driver, R., Wood-Robinson, C., Eds. (1980). Cognitive Development. Research in Science and Mathematics. Proceedings of an International Seminar. Leeds: The University of Leeds

Helm, H., Novak, J., Eds. (1983). Proceedings of the International Seminar "Misconceptions in Science and Mathematics". Ithaca: Cornell University

Novak J., Ed. (1987). Proceedings of the Second International Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol. I, II, III. Ithaca: Cornell University

Leider ist es bislang noch nicht zu einem engeren Meinungs- und Erfahrungsaustausch zwischen Naturwissenschaftsdidaktikern und Mathematikdidaktikern über die jeweiligen empirischen Ergebnisse und theoretischen Ansätze gekommen.

Zum Aufbau der Literaturliste

Wir haben die aufgenommenen Arbeiten in neun Gruppen eingeteilt:

g1 Zum Umfeld des Problems "Vorstellungen"

Hier finden sich Arbeiten, die sich ganz allgemein mit Problemen des Forschungsgebietes befassen.

g2 Alltagsvorstellungen und wissenschaftliche Vorstellungen

Es geht in dieser Gruppe um Arbeiten, die sich speziell mit der Frage der Beziehungen zwischen Alltagsvorstellungen und wissenschaftlichen Vorstellungen beschäftigen.

g3 Geschichtliche und individuelle Entwicklung von Vorstellungen

Viele Untersuchungen zeigen, daß bei Schülern/Studenten heute Vorstellungen auftreten, die auch in der historischen Entwicklung der Wissenschaft eine Rolle gespielt haben. Die hier eingeordneten Arbeiten gehen der Frage nach, welche Bedeutung die historische Entwicklung für die individuelle Entwicklung haben kann.

g4 Sprache und Vorstellungen

Viele Vorstellungen haben ihren Ursprung in der Alltagssprache. Um diesen Problemkreis geht es hier.

g5 Methoden zur Erfassung von Vorstellungen

Wir haben hier solche Publikationen eingeordnet, die Untersuchungsmethoden diskutieren.

g6 Untersuchungen zu Vorstellungen von Schülern und Studenten

Dies ist die umfangreichste Gruppe. Nach Sachgebieten geordnet (s. weiter unten) finden sich hier Arbeiten, die Auskunft über Vorstellungen in verschiedenen Bereichen geben.

g7 Unterricht unter Berücksichtigung von Vorstellungen der Schüler

Es finden sich hier Untersuchungen, in denen Unterricht, der Schülervorstellungen explizit berücksichtigt, im Mittelpunkt steht. Auch hier werden die Arbeiten nach Sachgebieten geordnet.

g8 Untersuchungen zu Vorstellungen von Lehrern

Entsprechend wie bei g6 werden hier Vorstellungen von Lehrern eingeordnet. Die Unterscheidung von Lehrern auf der einen und Schülern/Studenten auf der anderen Seite ist nicht immer ganz einfach. In der Literatur wird zum Beispiel manchmal auch dann bereits von Lehrervorstellungen gesprochen, wenn es sich um Lehrerstudenten in der berufsvorbereitenden Phase ihrer Ausbildung handelt. In der vorliegenden Bibliographie werden unter g8 nur Untersuchungen zu Vorstellungen praktizierender Lehrer aufgelistet.

g9 Vorstellungen und Lehrerbildung

Es geht hier um Konsequenzen, die aus den empirischen Untersuchungen und theoretischen Überlegungen für die Lehrerbildung gezogen werden. Eingeordnet werden hier solche Arbeiten, in denen entweder neue Konzepte für die Lehrerbildung auf einer "konstruktivistischen" Basis entwickelt werden oder in denen über die Erprobung solcher Ansätze berichtet wird.

Die Zuordnung von Beiträgen zu den einzelnen Gruppen ist nicht immer einfach. Wir hoffen aber in den meisten Fällen eine einigermaßen einleuchtende Zuordnung gefunden zu haben. Viele Beiträge sind in verschiedene Gruppen eingeordnet. Man erkennt dies bei den Zitaten daran, daß mehrere Schlagwörter (s. weiter unten) angegeben sind. Bei einem Forschungsfeld, das sich nach wie vor in der Entwicklung befindet, ist es sehr schwierig, ein Kategoriensystem zu finden, das für alle Entwicklungen offen ist, das sozusagen ohne Schwierigkeiten mitwächst. Das vorstehend skizzierte Kategoriensystem der Gruppen g1 bis g9 erwies sich Anfang der 80er Jahre als zweckmäßig. Neuere Entwicklungen im Forschungsfeld würden heute wohl zu einem etwas anderen System führen, wenn man es ganz neu entwerfen würde. Durch Ergänzungen aber versuchen wir, das System so zu erweitern, daß es jedenfalls den wichtigsten Aspekten auch des

heutigen Forschungsstandes gerecht werden kann.

Ergänzungen des Kategoriensystems erscheinen insbesondere in g1 nötig zu sein. Eingeordnet sind dort 668 Arbeiten verschiedener Ausrichtung und Schwerpunkte. Die Auswertung dieser vielen Arbeiten würde durch entsprechend gewählte weitere Schlagwörter sehr vereinfacht. Leider war es mir bislang nicht möglich, eine solche weitere Verschlagwortung vorzunehmen. Ergänzungen wären auch für die Bereiche Biologie und Chemie in g6 und g7 nötig. Hier fehlt bislang eine Aufteilung in Sachbereiche, wie sie für die Physik bereits vorliegt. Aber auch dort erscheinen weitere Unterteilungen notwendig zu sein. Dies gilt insbesondere für die 281 Arbeiten, die der Mechanik zugeordnet sind.

Schlagwörter

Die "Schlagwörter" g1 bis g9 kennzeichnen die vorstehend genannten neun Gruppen.

Für Arbeiten, die in die Gruppen g6, g7 und g8 eingeordnet sind, geben wir weitere Schlagwörter an. Diese betreffen zunächst die Fächer:

P: Physik
C: Chemie
B: Biologie

Findet sich bei den Publikationen der Gruppen g6, g7 und g8 keines dieser Schlagwörter, so handelt es sich entweder um eine Arbeit, in der Vorstellungen aller drei Fächer gleichermaßen eine Rolle spielen oder um eine Arbeit, die sich nicht speziell mit Vorstellungen eines der Fächer beschäftigt. Zu letzteren Arbeiten zählen z. B. solche, die sich mit übergreifenden Denkschemata, wie z. B. Kausalität, Reversibilität, Erhaltung oder Proportionalität, befassen.

Da die Anzahl der zur Physik erschienenen Arbeiten fast unüberschaubar groß geworden ist, haben wir dort die folgenden weiteren Untergliederungen vorgenommen.

E: Elektrizität
T: Wärme (Therm. Physik)
M: Mechanik (einschließlich der Mechanik der Flüssigkeiten und Gase sowie der Aggregatzustandsänderungen)
O: Optik
AT: Atome und Teilchen
AS: Astronomie (insbesondere Vorstellungen über die Erde und andere Himmelskörper im Weltall)
EN: Energie

Alle Arbeiten zur Physik, die nicht in diese Teilgebiete eingeordnet worden sind, erscheinen unter "g6, P (sonstige/others)". Um allzuviele Überschneidungen zwischen Chemie und Physik zu vermeiden, ordnen wir Untersuchungen zu Teilchen- und Atomvorstellungen der Physik zu und nicht auch noch der Chemie. Einige weitere Schlagwörter zum Bereich Physik kennzeichnen weitere Gebiete bzw. Begriffe. Sie spiegeln weniger eine Systematik als vielmehr die Interessen der Ersteller der Bibliographie.

ENT: Entropie
FLD: Feld
INF: Information
IRR: Irreversibilität
MAG: Magnetismus
Q: Quantenphysik
R: Relativistische Physik
STAT: Statistische Physik
S: Schall

Weitere allgemeine Schlagwörter [illegible]hen sich auf alle Arbeiten, die in die Gruppen g6, g7 und g8 eingeordne[illegible]en.

CTL: Vorstellungen (Konzeptionen[illegible] r- und Lernprozesses. Dieses Schlagwort kennzeichnet e[illegible]piri[illegible]e Untersuchungen zu Vorstellungen (von Schülern/Studenten bzw. Lehrern) zum Lehren und Lernen.
CSC: Vorstellungen (Konzeptionen) zur "Natur" der Wissenschaften. Erfaßt werden hier empirische Untersuchungen zu Vorstellungen von der "Natur und Reichweite" naturwissenschaftlicher Theorien und Erkenntnisse.
STS: Vorstellungen zum Nutzen naturwissenschaftlicher Kenntnisse und Verfahrensweisen im Raum der Technik und der Gesellschaft
GEN: Dieses Schlagwort kennzeichnet empirische Untersuchungen, in denen geschlechtsspezifische Unterschiede eine Rolle spielen.
OCI: Der Beitrag enthält Originalzitate aus Interviews oder Fragebögen
OIM: Der Beitrag enthält Originalzeichnungen der Befragten

Am Ende dieses Bandes findet sich eine Liste aller Schlagwörter.

Erläuterung der Zitate

Autorenname

Initialen des Vornamens

Erscheinungsjahr
(n.d. bedeutet: Erscheinungsjahr ist nicht bekannt)

Titel

Solomon, J. (1983). Learning about energy: How pupils think in two domains.
European Journal of Science Education 5, 1, 49-59
g6,g7,P,M,EN

Seitenzahl

Schlagwörter

Erscheinungsort
(Zeitschrift, Sammelband oder dgl)

Jahrgang oder Bandnummer

Heftnummer

Dateien der Bibliographie auf Computerdiskette

Die Bibliographie wird mit Hilfe des Literaturverwaltungsprogramms "Turbo Lit" (Version 3.1.) der Firma M. Krauss & W. Benner (Mauritiusstr. 15/ D 5403 Mülheim-Kärlich) geführt. Falls Kollegen über dieses Programm verfügen, kann der Datensatz auf Computerdiskette bereitgestellt werden. Für Kollegen, die ein anderes Verwaltungsprogramm benutzen, kann der Datensatz als ASCII Datei oder als WORD Datei (für IBM kompatible Rechner) auf Disketten überspielt werden, die mir zugesandt werden. Auf diesen Dateien werden die Einträge in alphabetischer Reihenfolge (nach dem Namen des ersten Autors) in der vorstehend erläuterten Form aufgelistet. Sie lassen sich von diesen Dateien in vorhandene Literaturverwaltungssysteme transformieren. Der gesamte Datensatz hat etwa 400kB. Falls die Disketten mit 360kB formatiert sind, müssen deshalb zwei Disketten geschickt werden.

(2) ZUM FORSCHUNGSGEBIET

Informelle Zusammenschlüsse

Das Forschungsgebiet, auf das sich die hier vorliegende Bibliographie bezieht ist sehr gut ausgebaut. Es dürfte sich um das Gebiet handeln, auf dem die meisten naturwissenschaftsdidaktischen Forschungsarbeiten entstehen. Die An-

zahl der Kolleginnen und Kollegen, die auf diesem Gebiet arbeiten, ist schwer einzuschätzen. Es gibt zwei weltweit operierende informelle Zusammenschlüsse, deren Mitgliederlisten etwa 500 Personen umfassen. Es handelt sich dabei um:

(a) Eine auf "privater" Basis operierende Gruppe nennt sich "Invisible College". Regelmäßig erscheinende "Newsletter" dienen zur Information über Trends und über Arbeiten der Mitglieder. Die "Newsletter" werden jeweils von Kollegen bzw. Kolleginnen herausgegeben, deren Institutionen über die nötigen Möglichkeiten verfügen. Das nächste Newsletter wird herausgegeben von: Prof. Dr. Hans Niedderer/Universität Bremen/Kufsteinerstr./D 2800 Bremen.

(b) Die zweite Gruppe ist als Special Interest Group von AERA (American Educational Research Association) institutionalisiert. Diese SIG gibt ebenfalls regelmäßig ein Newsletter heraus. Man kann Mitglied dieser Gruppe werden, ohne AERA anzugehören. Zur Zeit wird das Newsletter betreut von: Dr. Jeffrey Bloom/Queens University, Faculty of Education/Kingston, Ontario, Canada K7L 3N6.

Andere Bibliographien

Wie im Vorwort bereits erwähnt, gibt es einige weitere Bibliographien des hier dokumentierten Forschungsgebiets. Die beiden im folgenden zuerst genannten sind jeweils auf ein Fach beschränkt. Die Bibliographie von Giordan enthält auch Arbeiten zur Biologiedidaktik, die nicht zum hier dokumentierten Gebiet zählen. Am umfassendsten ist die letztgenannten, von Kollegen der University of Leeds zusammengestellte. Sie enthält etwa 1500 Einträge. Einige der zur Kategoriesierung verwendeten Schlagwörter sind der in der vorliegenden Bibliographie benutzten ähnlich oder gleich. Die mir am wichtigsten erscheinenden Arbeiten der ersten vier im folgenden genannten Bibliographien habe ich in die vorliegende Bibliographie aufgenommen (die aus der Bibliographie von Bredderman aufgenommenen Arbeiten finden sich in Anhang 1). Eine Liste der Arbeiten der fünften Bibliographie, die in der vorliegenden nicht vorhanden sind, findet sich in Anhang 2.

Maloney, D.P (1987). Cognitive physics research – a bibliography (2nd edition). Indiana University, Purdue at Fort Wayne

Giordan, A. (1987). Bibliographie concernant les recherches sur les conceptions des apprenants en biologie. Annales de didactique des sciences No. 2, Biodic LDES

Dykstra, D., Schroeder, S. (1987). Published materials in science education: alternative conceptions and cognitive development. Paper of the Departement of Physics, Boise State University

Bredderman, T. (1990). Research literature on alternative conceptual frameworks and conceptual change. University of Albany, Department of Educational Theory and Research

Charmichael, P., Driver, R., Holding, B., Phillips, I., Twigger, D., Watts, M. (1990). Research on students' conceptions in science: a bibliography. Children's Learning in Science Group. Leeds: The University of Leeds

Einige Hinweise auf Übersichtsartikel und Zusammenfassungen

Eine Bibliographie mit etwa 2 000 Literaturstellen ist für diejenigen, die sich in das Forschungsgebiet einarbeiten wollen, schwierig zu übersehen, auch wenn durch die Untergruppen und Schlagwörter bereits eine gewisse Strukturierung vorhanden ist. Im folgenden soll deshalb versucht werden, einige Hinweise auf Arbeiten zu geben, die sich – aus meiner Sicht – eignen, in das Forschungsfeld einzusteigen.

(a) Allgemeine Übersichten über das Forschungsgebiet

Driver, R., Erickson, G. (1983). Theories-in-action: some theoretical and empirical issues in the study of students' conceptual frameworks in science. Studies in Science Education 10, 37 – 60

Gilbert, J., Watts, M. (1983). Concepts, misconceptions and alternative conceptions: changing perspectives in science education. Studies in Science Education 10, 1983, 61 – 98

Hashweh, M. (1986). Towards an explanation of conceptual change. European Journal of Science Education 8, 1986, 129 – 289

Driver, R. (1989). Students' conceptions and the learning of science. International Journal of Science Education 11, 481–490 (Dies ist der einführende Artikel eines Themenheftes, das einen Überblick über Forschungsansätze des hier in Rede stehenden Gebietes gibt.)

Duit, R. (in press). Students' conceptual frameworks–consequences for learning science. In: Glynn, S., Yeany, R., Britton, B. (Eds.): The psychology of learning science. Hillsdale: Erlbaum

(b) <u>Tagungsbände</u>

Tagungsbände sind in besonderer Weise geeignet, einen Überblick über das Forschungsgebiet zu geben. Die drei oben bereits genannten Tagungsbände (Archenhold, u. a. 1980; Helm, H., Novak, J., 1983; Novak, J., 1987) dokumentieren die wohl größten Tagungen auf dem hier in Rede stehenden Forschungsgebiet. Sie spiegeln zugleich die Entwicklung des Gebietes. Weitere Tagungsbände sind:

Duit, R., Säljö, Eds. (1988). Students' conceptions of subject matter content. Proceedings of a Symposium at the 2. European Conference on Learning and Instruction, Tübingen, Sept. 1987. Kiel: IPN Reports-in-Brief

Adey, P., Ed. (1989). Adolescent development and school science. London: Falmer Press

(c) <u>Bücher</u>

Es gibt bereits eine Reihe von Büchern, in denen versucht wird, die wichtigsten Ansätze und Ergebnisse zusammenzufassen. Als Standortbestimmung für die weitere Planung des Forschungsgebietes diente in der Bundesrepublik Deutschland z. B. der folgende Band:

Duit, R., Jung, W., Pfundt, H., Hrg. (1981). Alltagsvorstellungen und naturwissenschaftlicher Unterricht. Köln: Aulis

Eine Zusammenfassung der wichtigsten Ergebnisse (vor allem im Bereich der Physik) und Grundideen des Forschungsgebietes für den Lehrer bietet ein Themenheft einer Zeitschrift:

Duit, R., Jung, W., Rhöneck, Ch. v., Hrg. (1986). Alltagsvorstellungen - Energie - Elektrik - Optik - Mechanik - Wärme - Teilchen - Stoff. Naturwissenschaften im Unterricht - Physik Chemie 34

Ebenfalls auf eine Zusammenfassung der Ergebnisse von Forschungsarbeiten (vor allem auf dem Gebiet der Physik) konzentriert sich:

Driver, R., Guesne, E., Tiberghien, A., Eds. (1985). Childrens' ideas in science. Milton Keyne: Open University Press

Etwas allgemeiner angelegt sind die folgenden beiden Bände:

Osborne, R., Freyberg, P., Eds. (1985). Learning in Science. The implication of children's science. Auckland, London: Heinemann

Giordan, A., Vecchi, G. de (1987). Les origines du savoir. Neuchatel, Paris: Delachaux & Niestle

(d) <u>Zusammenfassung von Untersuchungen zu Vorstellungen in einzelnen Gebieten</u>

Lehrer, Lehrbuchautoren und Entwickler von Curriculummaterialien werden vor allem daran interessiert sein, zu erfahren, mit welchen Vorstellungen in bestimmten Bereichen (z.B. beim elektrischen Stromkreis) zu rechnen ist. Die Untergliederung der Gruppe "g6" bietet den Zugang zu allen in der Bibliographie vertretenen Arbeiten zu dem betroffenen Gebiet. Zu einigen Gebieten gibt es auch Zusammenfassungen.

Das unter (c) genannte Themenheft "Alltagsvorstellungen" faßt Ergebnisse zu den Gebieten Energie, Elektrik, Optik, Mechanik, Wärme und Teilchen zusammen. Im ebenfalls unter (c) genannten Band von Driver u. a. finden sich Zusammenfassungen zu den Gebieten Optik, Elektrik, Wärme, Mechanik (Kraft und Bewegung), Teilchen und Astronomie. Eine weitere gute Übersicht zum Gebiet "Kraft und Bewegung" bietet:

McDermott, L. (1984). Research and conceptual understanding in mechanics. Physics Today, July 1984, 24 - 32

In deutschem Sprachraum wären Beiträge im Themenheft "Kraftbegriff" der Zeitschrift "Naturwissenschaften im Unterricht-Physik/Chemie" (Heft Mai 1988) zu nennen oder Abschnitte aus:

Schecker, H. (1985). Das Schülerverständnis zur Mechanik. Dissertation, Universität Bremen

Über Untersuchungen im Bereich der Elektrizitätslehre informiert umfassend ein Tagungsband:

Duit, R., Jung, W., Rhöneck, Ch. v., Hrg. (1985). Aspects of understanding electricity. Kiel: IPN

Für den Bereich des Teilchenmodells der Materie liegt ebenfalls ein Tagungsband vor, der den heutigen Wissensstand zusammenfassend präsentiert:

Lijnse, P.L., Licht, P., de Vos, W., Waarlo, A.J., eds. (1990). Relating macroscopic phenomena to microscopic particles. Utrecht: The University of Utrecht, Centre for Science and Mathematics Education

Leider gibt es weder im Bereich der Chemie noch im Bereich der Biologie meines Wissens zur Zeit ähnliche Zusammenfassungen zu einzelnen Teilgebieten. Dort bleibt also nur der Zugang über die Bibliographie unter "g6, C" bzw. "g6, B".

(3) TRENDS IM FORSCHUNGSGEBIET "VORSTELLUNGEN UND NATURWISSENSCHAFTLICHER UNTERRICHT"

Übersichtstabellen

Die Tabellen 1 und 2 geben einen Überblick über Stand und Entwicklung des Forschungsgebietes. Tabelle 1 gibt auf der Basis der vorliegenden Ausgabe der Bibliographie die Anzahl der Arbeiten in den Gruppen g1 bis g9 an, die in bestimmten Zeitabschnitten publiziert worden sind. Von 1971 bis 1990 sind Unterteilungen in Vierjahresabschnitte gewählt worden. Es zeigt sich, daß Mitte der 70er Jahre der heutige Boom an Forschungsarbeiten einsetzte und daß er bis heute unvermindert anhält. Der Schwerpunkt der aufgenommenen Arbeiten liegt in g6, d.h. rund die Hälfte von ihnen beschäftigen sich mit Untersuchungen zu Schülervorstellungen zu naturwissenschaftlichen Phänomenen, Begriffen und Prinzipien. Dabei dominiert die Physik bei weitem. Erst seit Beginn der 80er Jahre kommen Untersuchungen zu neuentwickelten Unterichtsansätzen (g7) in nennenswertem Umfang hinzu. Seit Mitte der 80er Jahre ist ein deutlicher Trend zu einer allgemeineren Orientierung abzulesen. Er spiegelt sich in der Tabelle 1 vor allem in den Zeilen für g8 (Vorstellungen der Lehrer), g9 (Konsequenzen für die Lehrerbildung), CTL (Vorstellungen vom Lernprozeß) und SCS (Vorstellungen zur Natur und Reichweite naturwissenschaftlicher Kenntnisse).

In Tabelle 2 sind die Untersuchungen zu Schülervorstellungen (also die Einträge in g6) aufgegliedert nach physikalischen Teilgebieten und nach Chemie und Biologie. Es zeigt sich einerseits die große Dominanz der Physik. Andererseits dürfte auffallen, daß es auch in diesem Fach noch große Lücken unseres Wissens über Schülervorstellungen gibt. So befassen sich gerade 11 der aufgenommenen Artikel mit moderner Physik (dort vor allem mit der Quantenmechanik). Aber auch zu so klassischen Gebieten der Physik wie Schall oder Magnetismus gibt es nur wenige Untersuchungen. Es kann also keine Rede davon sein, daß Untersuchungen zu Schülervorstellungen nicht mehr nötig seien. Das Gegenteil ist der Fall. Unser Wissen darüber ist lückenhaft. Tabelle 2 und die entsprechenden Literaturlisten unter g6 mögen helfen, solche Lücken aufzuspüren und zu beseitigen.

	<1960	60-70	71-74	75-78	79-82	83-86	87-90	Summe
g1	9	5	19	45	91	154	165	668
g2	-	2	1	2	3	8	5	21
g3	-	-	4	3	3	14	16	40
g4	6	17	11	12	14	18	19	97
g5	2	1	5	10	53	74	86	231
g6	36	38	38	79	210	365	355	1121
g6,P	8	15	19	41	129	262	239	713
g6,C	3	2	5	8	23	28	58	127
g6,B	10	8	12	13	21	68	64	196
g7	-	7	6	13	26	115	156	323
g7,P	-	-	1	10	16	70	107	204
g7,C	-	5	-	3	1	2	15	26
g7,B	-	-	1	1	4	13	17	36
g8	3	-	-	-	2	11	53	66
g9	-	-	-	-	-	2	27	29
CTL	-	-	-	-	2	7	39	48
CTL	-	-	-	-	2	-	19	21
Gesamt	47	69	82	150	339	596	708	1991

Tab. 1.
Anzahl von Beiträgen in den Gruppen g1 bis g9 - Jahreszeiträumen zugeordnet. In der Spalte "Summe" findet sich die Gesamtzahl der z. Zt. in der Bibliographie in die Gruppen eingeordneten Beiträge.

MECHANIK	281	Kraft und Bewegung/Arbeit, Energie, Leistung/ Geschwindigkeit, Beschleunigung/Gravitation Druck/Dichte/Schwimmen und Sinken
ELEKTRIK	146	einfache, verzweigte Stromkreise/Modelle des Stromflusses/Stromstärke, Spannung, Widerstand/Elektrostatik/Elektromagnetismus/ Gefahren des Stromes
WÄRME	68	Wärme und Temperatur/Wärmeausbreitung/Ausdehnung bei Erwärmung/Zustandsänderungen, Gefrieren, Sieden/Erklärung der Wärmephänomene im Teilchenmodell
OPTIK	69	Licht/Lichtausbreitung/Sehen/ Farben
TEILCHEN	60	Struktur der Materie/Erklärung von Phänomenen (z.B. Wärme, Zustandsänderungen)/Atomvorstellungen/Radioaktivität
ENERGIE	69	Energieumwandlung/ - erhaltung/ - entwertung
ASTRONOMIE	36	Vorstellungen zur Erde und anderen Himmelskörpern/Satelliten
"MODERNE" PHYSIK	11	Quantenmechanik/spezielle Relativitätstheorie
CHEMIE	132	Verbrennung/Oxidation/chemische Reaktionen/ Umwandlungen der Stoffe/chemisches Gleichgewicht/Symbole/Molkonzept
BIOLOGIE	208	Pflanzenernährung/Photosynthese/Osmose/ Leben/Herkunft des Lebens/Evolution/Blutkreislauf/Genetik/Gesundheit/Wachstum

Tab. 2: Untersuchungen zu Schülervorstellungen in verschiedenen Gebieten (die Zahlen geben die Anzahl der Artikel an, die in der vorliegenden Ausgabe der Bibliographie aufgeführt sind)

Zu dem, was mit "Vorstellungen" gemeint ist

Im Titel der vorliegenden Bibliographie sowie in dieser Einführung wird ganz bewußt ein recht vager Terminus, nämlich Vorstellungen, verwendet. Alltagsvorstellungen sind dabei solche, die ihren Ursprung in Alltagserfahrungen haben. Im deutschen Sprachraum sind einige weitere Termini vorgeschlagen worden, so

z. B. Konzept oder Vorverständnis. Im internationalen Raum gibt es eine sehr große Zahl weiterer Termini (z.B. alternative frameworks, misconceptions, conceptions, notions, belief systems und viele andere). Diese Termini sind keineswegs gleichbedeutend, sie kennzeichnen vielmehr spezielle Aspekte des Gesamtfeldes im Rahmen bestimmter theoretischer Konzeptionen (s. dazu meine Übersicht in Duit, 1987, g1; S. 8). Die große Zahl von Termini signalisiert eine Theorievielfalt im Forschungsgebiet. Dies wäre positiv betrachtet. Eher negativ betrachtet, ist unverkennbar, daß es bislang lediglich Ansätze zu übergreifenden Theoriebildungen gibt. Die Verwendung eines so vagen Terminus wie "Vorstellung" kann deshalb auch als Ausdruck einer gewissen Theorielosigkeit (wenn man eine übergreifende Theorie im Auge hat) angesehen werden.

Unverkennbar ist selbstverständlich ein breiter Konsensbereich der unterschiedlichen theoretischen Ansätze. Ansonsten hätte sich das Forschungsgebiet gar nicht herausbilden können. Es geht dabei um die folgende Auffassung vom Lernen. Lernen wird nicht als ein passives Übernehmen von Wissen angenommen. Lernen wird vielmehr als sehr aktiver Prozeß gesehen – als Prozeß, bei dem der Lernende aktiv sein Wissen selbst konstruieren muß, auf der Basis der Vorstellungen (Konzepte, ...), die er bereits vorher erworben hat. Diese bereits erworbenen Vorstellungen, d. h. diese bereits in der kognitiven Struktur abgespeicherten geistigen Entwürfe, spielen eine ganz zentrale Rolle im Lernprozeß. Sie beeinflussen die Interpretation der sinnlichen Wahrnehmungen und deren Weiterverarbeitung. Die vorstehend ganz kurz (und sicherlich in mancher Hinsicht auch verkürzt) dargestellte Auffassung vom Lernen ist die Grundidee, die im Durchschnitt aller Ansätze im Forschungsgebiet liegt oder, in einem anderen Bild ausgedrückt, die als gemeinsamer Nenner angesehen werden kann. Für diesen gemeinsamen Nenner hat sich die Bezeichnung "konstruktivistische" Sichtweise durchgesetzt, zunächst vor allem im angelsächsischen Raum, seit kurzem auch in der Bundesrepublik Deutschland (s. dazu auch weiter unten).

Zur Entstehung des Forschungsgebiets in der Mitte der 70er Jahre

Diese "konstruktivistische" Grundidee ist keineswegs neu. Sie liegt z. B. Ausubels pädagogischer Psychologie zugrunde, kann aber weit in die Geschichte der Pädagogik und des naturwissenschaftlichen Unterrichts zurückverfolgt werden (s. Jung, 1985, g1; S. 18). Etwa seit Beginn des 20. Jahrhunderts gibt es auch ein Interesse, die Vorstellungen der Schüler im Bereich der Naturwissen-

schaften kennenzulernen. Piagets Arbeiten sind hier natürlich als der Meilenstein zu nennen Zu erinnern ist im deutschen Sprachraum auch an die Kette von Arbeiten im Bereich der Naturlehre, die beginnend mit Banholzer und Zietz in den 30er Jahren, allerdings unterbrochen durch den 2. Weltkrieg, bis zur großen Bildungsreform Ende der 60er Jahre reichen.

Seit etwa der Mitte der 70er Jahre gibt es - weltweit (wobei dies vor allem für die sogenannte "westliche Welt" gilt) - geradezu einen Boom von Forschungsarbeiten (s. Tabelle 1). Es scheint so zu sein, daß ein Zusammentreffen der Interessen zweier Gruppen den entscheidenden Anstoß für diese Forschungsarbeiten gegeben hat. Zu den Initiatoren zählen nämlich einerseits Fachdidaktiker, also Personen, denen es um die Verbesserung des Unterrichts ging. Die Curriculumbewegung der 60er und frühen 70er Jahre hatte nicht den durchschlagenden Erfolg gebracht, den man sich erhofft hatte. Die Orientierung an den grundlegenden Konzepten der Wissenschaften ("structures of the disciplins") hatte jedenfalls nicht dazu geführt, Lernprobleme wesentlich zu mindern. Nach wie vor erwies es sich als äußerst schwierig, die Schüler von ihren vorunterrichtlichen Vorstellungen zu den wissenschaftlichen zu führen. Auf der anderen Seite waren es Vertreter der Kognitionspsychologie, die sich vom bislang beherrschenden behavioristischen Ansatz lösten. Dieser war eher der oben skizzierten "passiven" Sicht des Lernprozesses zuzuordnen, die neuen Ansätze dagegen der "aktiven". Die Interessen beider Gruppen trafen sich, es kam zu mannigfaltigen Kooperationen. Die Schwerpunkte der Forschungen lagen in der Untersuchung von "Vorstellungen". Die Fachdidaktiker waren daran interessiert, zunächst einmal die Vorstellungen in den wichtigsten naturwissenschaftlichen Gebieten festzustellen, die Schüler in den Unterricht mitbringen und die Veränderung dieser Vorstellungen im Verlaufe des Unterrichts zu verfolgen. Die kognitionspsychologisch ausgerichteten Forschungen waren ganz allgemein an der Rolle der Vorstellungen beim Lernen bzw. beim Problemlösen interessiert. Naturwissenschaftliche (vor allem physikalische) Sachgebiete erwiesen sich als sehr geeignetes Forschungsfeld. Der Schwerpunkt der Forschungsarbeiten lag also zunächst in der Gruppe, die im Rahmen der vorliegenden Bibliographie mit "g8: Untersuchungen zu Vorstellungen von Schülern und Studenten" bezeichnet wird (s. Tabelle 1).

Weiterentwicklung I: Konsequenzen für den Unterricht

Zunehmend befaßt man sich nicht allein mit der "Erhebung" von Vorstellungen und mit der Konstatierung, daß diese im herkömmlichen Unterricht schwer zu verändern sind. Untersuchungen, in denen Konsequenzen aus den vorstehend genannten Resultaten nicht nur theoretisch entworfen, sondern auch empirisch untersucht werden, nehmen einen immer größeren Raum ein. In der Bibliographie erkennt man es daran, daß auch die Anzahl der Untersuchungen unter "g7: Unterricht unter Berücksichtigung von Vorstellungen der Schüler" stark zunimmt (s. auch Tabelle 1).

Die wichtigsten "Maßnahmen", die zur Verbesserung des Unterrichts entwickelt werden, scheinen mir die folgenden zu sein (s. etwas ausführlicher in Duit, 1987, g1; S. 8):

- Die Sachstruktur des Unterrichts wird geändert.
- Neue Lehr- und Lernhilfen (neue Lehrbücher, neue Experimente, insbesondere auch neue Computerprogramme) werden entwickelt.
- Neue Lehrstrategien werden erprobt. Dabei handelt es sich nicht immer um "wirklich" neue Strategien. Es finden sich dort auch einige "alte Bekannte", die man bislang z. B. unter "entdeckendem Lernen" eingeordnet hatte.
- Strategien des Meta-Learning werden eingesetzt, d. h. es wird versucht, den Schüler zu einer neuen "Vorstellung" von seinem Lernprozeß zu führen (s. dazu auch weiter unten).
- Es wird versucht, Lehrer vom "neuen" Bild des Lernens (also der oben skizzierten "aktiven" Sicht) zu überzeugen, um dadurch anderes Lehrverhalten zu erzielen.

Weiterentwicklung II: Von Vorstellungen über naturwissenschaftliche Phänomene, Begriffe und Theorien zu Vorstellungen über die Natur und Reichweite wissenschaftlicher Wissensbestände sowie über den Lernprozeß

Wie erwähnt, startete das Forschungsgebiet Mitte der 70er Jahre mit Untersuchungen der Vorstellungen von Schülern bzw. Studenten über naturwissenschaftliche Phänomene, Begriffe und Theorien. Inzwischen nimmt man weitere "Vorstellungen", die das Erlernen bestimmen, in den Blick. Dazu zählen zunächst einmal Vorstellungen zur "Natur und Reichweite" naturwissenschaftlicher Wissensbestände. Es ist einleuchtend, daß das "Bild der Naturwissenschaften", das sich ein Schüler macht, beeinflußt, wie er/sie Naturwis

senschaften lernt. Einen weiteren Schritt zu sehr allgemeinen Vorstellungen, die Lernen beeinflussen, geht man mit der Erforschung des Einflusses des "Bildes", das sich Schüler vom eigenen Lernen machen (s. dazu die unter dem Schlagwort CTL eingeordneten Arbeiten; S. 209 ff). Wer z. B. Lernen vorwiegend als Einfüllen von Lehrstoff ansieht, den der Lehrer bzw. ein Lehrbuch präsentiert, lernt entsprechend, d. h. nimmt eine Haltung ein, die weiter oben als "passiv" bezeichnet worden ist. Schließlich werden auch die Einstellungen und Interessen der Schüler sowohl zu naturwissenschaftlichen Wissensbeständen wie auch zum Lernen insgesamt in den Blick genommen (s. die Artikel mit dem Schlagwort CSC; S. 205 ff).

Während ursprünglich der Schüler bzw. Student (also der Lernende) fast ausschließlich im Blickpunkt stand, wird zunehmend versucht, auch die Vorstellungen der Lehrer zu berücksichtigen (s. g8). Dabei handelt es sich um Vorstellungen in der gleichen Breite, wie sie heute beim Schüler berücksichtigt werden.

Die hier skizzierten Ausweitungen des Forschungsgebietes sind sehr tiefgreifend. Sie ergeben sich einerseits zwingend aus dem Grundansatz, daß Lernen ein aktiver Konstruktionsprozeß auf der Basis der bereits erworbenen "Vorstellungen" (Konzepte, Einstellungen, Interessen) ist. Sie können das Arbeitsgebiet aber andererseits zu einem Punkt führen, an dem die Komplexität des untersuchten Feldes nicht mehr zu bewältigen ist. Die Ausweitungen haben ja von einer Reduktion auf einen wichtigen Aspekt zu immer größerer Komplexität geführt. Es wird nunmehr in vielen Ansätzen versucht, die "volle" Komplexität des Unterrichts in den Blick zu nehmen. Es muß abgewartet werden, ob dies gelingt.

Weiterentwicklung III: Die theoretischen Ansätze

Die Fachdidaktiker im deutschsprachigen Raum, die Mitte der 70er Jahre das Forschungsgebiet initiierten, standen in einer langen Tradition, nämlich im Unterricht dort anzufangen, wo sich der Schüler befindet. Dies bedeutete auch, die Vorstellungen der Schüler angemessen zu berücksichtigen. Ähnliche Traditionen hat es in anderen Ländern sicher ebenfalls gegeben. Eine weltweit beachtete und akzeptierte Neuformulierung dieser Traditionen hat Ausubel gegeben. Sein Dictum "The most important single factor influencing learning is

what the learner already knows. Ascertain this and teach him accordingly" wurde und wird wohl auch heute von den meisten Forschern als zentraler Aspekt der Arbeit akzeptiert. Interessant ist es, die Rolle Piagets zu betrachten. Sie war nämlich durchaus zwiespältig. Auf der einen Seite standen alle Forscher sozusagen auf den Schultern von Piaget. Ohne seine theoretischen Ansätze, ohne seine grundlegenden Untersuchungen und ohne seine Interviewtechniken wären viele Unternehmungen sicher ganz anders verlaufen. Auf der anderen Seite aber setzte sich das neue Forschungsgebiet ganz bewußt von Piaget ab. Man war - jedenfalls sehr häufig - der Auffassung, daß die "inhaltlichen" naturwissenschaftlichen Vorstellungen (z. B. zum Sehen, zur Wärme, zum Begriff des Tieres) eine größere Bedeutung für den Lernprozeß haben, als die sehr allgemeinen Denkoperationen nach Piaget. Die Auseinandersetzungen zwischen "Piagetians" und "Alternative Frameworkers" wurden eine Zeit lang sogar mit beträchtlicher Schärfe geführt. Es hat den Anschein, daß sich heute eine vermittelnde Position durchgesetzt hat. Es wird jedenfalls meist anerkannt, daß beide Gesichtspunkte, nämlich "allgemeine Denkoperationen" wie "Vorstellungen" eine wichtige Rolle spielen.

Die zweite oben genannte Gruppe der Initiatoren des Forschungsgebietes, nämlich Vertreter der Kognitionspsychologie, haben wichtige theoretische Ansätze in das Forschungsgebiet eingebracht. Netzwerktheorien und Theorien der Informationsverarbeitung mit dem Computer als leitendes Paradigma sind hier beispielsweise zu nennen.

Zweifellos haben wissenschaftstheoretische Ansätze, die mit den Namen von Hanson, T. S. Kuhn, Lakatos und Feyerabend verbunden sind, einen ganz wesentlichen Einfluß gehabt. Auch sie haben ganz entscheidend dazu beigetragen, daß sich das Forschungsgebiet bildete und schnell wuchs. Dies ist auch gar nicht erstaunlich, denn schließlich spielt in diesen Ansätzen die Idee eine zentrale Rolle, daß alle Erkenntnis "theoriegeleitet", d. h. geleitet durch die herrschenden Vorstellungen ist.

Die starke Aufmerksamkeit, die Forschung auf dem hier in Rede stehenden Gebiet seit der Mitte der 70er Jahre gewidmet wird, geht also nicht zuletzt auch darauf zurück, daß wichtige Strömungen wissenschaftlichen Denkens aufgenommen und weitergeführt wurden. Die Forschungen lagen - so betrachtet - "im Trend der Zeit". Es sind selbstverständlich nicht allein die genannten wissenschaftstheoretischen Positionen "verarbeitet" worden. Beeinflußt ist das For-

schungsgebiet mittelbar auch durch neues naturwissenschaftliches Denken, das durch das Schlagwort der Selbstorganisation offener Systeme hier nur kurz gekennzeichnet werden kann. Dieses "Denken" seinerseits hat vielfältige Beziehungen zu Ansätzen der Künstlichen Intelligenz. In die skizzierten Strömungen fügt sich die "Wiederentdeckung" konstruktivistischer Ansätze nahtlos ein. Sie haben für das Forschungsgebiet "Vorstellungen und naturwissenschaftlicher Unterricht" eine große Bedeutung erhalten.

Etwa seit Beginn der 80er Jahre werden konstruktivistische Ansätze für das Forschungsgebiet ganz explizit nutzbar gemacht. Dies gilt in großer Breite. Einerseits nämlich geht es um persönlichkeitstheoretische Ansätze (wie z. B. von G. Kelly), andererseits um sozialpsychologische Ansätze (wie z. B. von Vygotsky). So fruchtbar die Einbeziehung solcher konstruktivistischen Ansätze auch ist, so gibt es doch einen unübersehbaren Trend im Forschungsgebiet, der mit aller Vorsicht und Skepsis zu sehen ist, nämlich die Arbeiten im gesamten Gebiet in Bausch und Bogen nunmehr mit dem Wort konstruktivistisch zu belegen. Denn allzuhäufig verbirgt sich hinter diesem "Label" kaum mehr als die oben skizzierte "aktive" Sicht des Lernens. Diese Idee ist aber zu allgemein, um als theoretische Grundlegung des gesamten Gebiets fruchtbar werden zu können. Wenn man von einer solchen oberflächlichen Übernahme eines "trivialen" Konstruktivismus absieht, so hat die Sichtweise auch in den nächsten Jahren dem Forschungsgebiet wesentliches zu bieten. Sie gibt Anregungen zur Entwicklung neuer Ansätze und zur Einbeziehung einer größeren Breite von Aspekten, die das Lernen in den Naturwissenschaften beeinflussen.

Reinders Duit: INTRODUCTION

(1) HOW TO USE THE BIBLIOGRAPHY

Aims of our collection of literature

Considerable attention has been paid to research on students' notions (students' conceptions) since the middle of the 1970s. We began collecting papers when we started research in this field some 13 years ago. We wanted to form a comprehensive picture of what had already been done in order to avoid "inventing the wheel" again. We have kept on collecting papers because we feel this to be the best way to keep track of what is going on in a rapidly expanding research field. We hope that the present bibliography may help colleagues to keep an eye on developments, or to form an initial impression when starting research.

We would like to accompany the bibliography with a request:

Please send your new articles or articles not contained in the bibliography so far, especially articles which are not published in journals, proceedings, books or the like. We will add your contributions to a supplementary or new edition of the present bibliography.

Unfortunately, we must draw your attention to the following:

Although our collection of literature may be used by anyone who visits the IPN, it is not possible for us to make copies of publications named in our lists. In this case please contact the authors themselves.

The main emphasis of the bibliography

Main emphasis of the bibliography is physics, chemistry and biology education but also studies on earth science are considered. They are listed in the groups g6, g7 and g8 under "others". Research on students' notions is not only carried out in science. For mathematics in particular many interesting papers are available. The following proceedings may provide valuable access to this field of research:

Archenhold, W. F., Orton, A., Driver, R., Wood-Robinson, C., Eds. (1980). Cognitive Development. Research in Science and Mathematics. Proceedings of an International Seminar. Leeds: The University of Leeds

Helm, H., Novak, J., Eds.(1983). Proceedings of the International Seminar "Misconceptions in Science and Mathematics". Ithaca: Cornell University

Novak J., Ed. (1987). Proceedings of the Second International Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol. I, II, III. Ithaca: Cornell University, 1987

A close cooperation of science and mathematics educators concerning students' conceptions research so far has not taken place. Here an important field of valuable work is waiting for the attention of researchers.

The structure of the bibliography

We have divided the works into nine groups:

g1 General considerations concerning research in this area

This comprises works which deal quite generally with this field of research.

g2 Everyday notions and scientific notions

This group deals specifically with relations between everyday notions and scientific notions.

g3 Development of notions in the history of science as compared to development of notions in individuals

Many studies have shown that notions occur among pupils today which also played a role in the historical development of science. The work of this group investigates the significance of historical development for the development of notions in the individual.

g4 Language and notions

Many notions originate in everyday language, a problem area investigated here.

g5 Methods of investigation

To this group we have assigned publications which discuss methods of investigation.

g6 Investigations of students' notions

This is by far the largest group and contains works which give information on notions in various areas. The works are divided into thematic areas (see below).

g7 Instruction taking students' notions into account

This group comprises investigations concentrating on instruction in which students' notions are taken into account. Again the works are divided into thematic areas.

g8 Investigations of teachers notions

Teachers' conceptions of various kinds are put into this group, as in g6 the works are divided into thematic areas. To differentiate between students' and teachers' conceptions is sometimes not easy. In literature occasionally student teachers' conceptions are called teachers' conceptions. The present group of the bibliography only contains studies on conceptions of teachers who already work in school practice.

g9 Notions and teacher training

Trends in the research field described later forced us to open this group some 5 years ago. There was a growing number of papers on consequences of students' conceptions research on teacher training. Studies in which new approaches for teacher training (based at the constructivistic view) are developed and which report on empirical studies about the evaluation of such approaches are put into the group g9.

It is not always easy to assign particular work to a particular group. We hope, however, that in most cases the most obvious group has been chosen. Many contributions are assigned to several groups and are therefore accompanied by several keywords (see below).

In a research area still in rapid progress it is rather difficult to find a system of classifying categories which is open to new trends. The system of the groups g1 to g7 appeared to be suited for this purpose in 1980. Difficulties have more recently occurred which we have tried to compensate for by opening two further groups (g8 and g9) and by adding further keywords (see below). We hope that the enlarged system of groups and keywords is suitable to cover at least the main aspects of the present research field.

Further keywords are necessary for the many articles put into group g1. The many different general aspects discussed in the articles listed are not adequately portrayed by simply the authors in alphabetical order. Hopefully there will be some time in future to develop a set of appropriate keywords and to

categorize the articles which have so far only been listed. Articles listed in groups g6 and g7 also require a more advanced set of keywords. There are so many studies in some of the sections that it would ease access if more keywords that point to science topics would be added. This is also true for physics where a fairly developed set of keywords is already in use. But it would be valuable to make further distinctions between the 281 studies on mechanics (keyword g6,P,M). Such an enlargement is even more necessary in biology and chemistry sections.

Keywords

The "keywords" g1 to g9 represent the above mentioned nine groups.

For works assigned to the groups g6, g7 and g8 we indicate further keywords. These apply first to the subjects:

P: physics
C: chemistry
B: biology

If a publication in group g6, g7 or g8 is not followed by one of these keywords, it does not deal specifically with notions relating to one of these subjects. Publications of this type include those which deal, for example, with general thought schemata such as causality, reversibility, conservation or proportionality.

As a vast amount of publications are available for the area of physics, we have introduced the following subdivisions:

E: electricity
T: heat (thermal physics)
M: mechanics (including mechanics of liquids and gases as well as changes of state of matter)
O: optics
AT: atoms and particles
AS: astronomy (including notions of the earth and other bodies in the universe)
EN: energy

Those works which are not included in any of these subcategories are to be found under "others". To avoid too many overlaps between chemistry and physics we assign studies on notions concerning particles and atoms to the

area of physics alone.

There are a number of further keywords indicating further areas or concepts. They are not intended to be a systematic catalogue, but rather a reflection of the compilers' interests.

ENT:	entropy
FLD:	field
INF:	information
IRR:	irreversibility
MAG:	magnetism
Q:	quantum physics
R:	relativistic physics
STAT:	statistical physics
S:	sound

Further keywords refer to articles put into the groups g6, g7 and g8.

- CTL: Conceptions of the teaching and learning process. This keyword emphazises empirical investigations on conceptions (of students or teachers) on teaching and learning.
- CSC: Conceptions (on the "nature and range") of science. This keyword is used for empirical studies in which conceptions of science play a role.
- STS: Conceptions on the use of science for technology and society. Under the heading of "STS" research and development, work is carried out on the use of science outside science. Empirical studies investigating notions of such uses in technology and society are marked by the keyword STS.
- GEN: Empirical studies in which gender differences are investigated are marked by GEN.
- OCI: The article contains original quotations from interviews, questionnaires and the like.
- OIM: The article contains original drawings by students or teachers.

A list of all keywords is given at the end of this volume.

Explanations of the entries

Author's surname

Initials of first name(s)

Year of publication (n.d. indicates that the year of publication is not known)

Title

Solomon, J. (1983). Learning about energy: How pupils think in two domains.
European Journal of Science Education 5, 1, 49-59
g6,g7,P,M,EN

Keywords

Place of publication (journal, anthology, etc)

Year or volume number

Issue number

page number

Files of the bibliography on floppy discs

A German program is used for storage and retrieval of the bibliography's entries. Colleagues who want to transfer the files of the bibliography to their program may receive a copy. Please send your floppy. I use an IBM compatible PC. The file is available in ASCII code or in WORD. More than 360 kB are needed. If you have 360 kB floppies please send two of them. The files contain the entries (an example is given above) of the bibliography in alphabetical order (first author).

(2) REMARKS ON THE RESEARCH FIELD

Informal groups of researchers

There are many colleagues around the world working in the field of students' conceptions which is one of the most active fields in the area of science education. The membership lists of two worldwide operating groups contain about 500 names. These groups are:

(a) **The "Invisible College".** This is a group started some 10 years ago by John Gilbert to support international cooperation. This is a "private" enterprise. Colleagues who have the facilities (e.g. members of research institutes) edit a newsletter that reports about trends in the field and also contains hints on the new articles of the members. The editor of the next (1991) edition will be Prof. Dr. Hans Niedderer/University of Bremen/ Kufsteinerstr./ D 2800 Bremen/ Germany. Please contact Hans Niedderer if you want to join the group.

(b) **Special Interest Group "Subject structure and conceptual change" of the American Educational Research Association (AERA).** This SIG also issues newsletters (two newsletters a year). It is possible to become a member of this group without being a member of AERA. If you are interested in this group, please contact Dr. Jeffrey Bloom/Queens University, Faculty of Education/ Kingston, Ontario, Canada K7L 3N6 who is in charge of this group at the moment (1991).

Other Bibliographies

As has been mentioned in the foreword there are some other bibliographies in the field of students' conceptions research available. Five are listed below. The first is restricted to physics, the second to biology. The second also contains publications on research work in biology education that does not belong to the research documented here. The bibliography of Charmichael et al is the largest and most elaborate. It contains some 1500 entries. Some of the keywords used there are similar or even identical with the keywords employed in the present bibliography. The main entries in the bibliographies one to four are also contained in the present bibliography (entries from Bredderman's bibliography in appendix 1). Entries which are contained in the fifth bibliography but not in the present one are listed in appendix 2, but they have not been categorized so far.

Maloney, D.P (1987). Cognitive physics research – a bibliography (2nd edition). Indiana University, Purdue at Fort Wayne

Giordan, A. (1987). Bibliographie concernant les recherches sur les conceptions des apprenants en biologie. Annales de didactique des sciences No. 2, Biodic LDES

Dykstra, D., Schroeder, S. (1987). Published materials in science education: alternative conceptions and cognitive development. Paper of the Department of Physics, Boise State University

Bredderman, T. (1990). Research literature on alternative conceptual frameworks and conceptual change. University of Albany, Department of Educational Theory and Research

Charmichael, P., Driver, R., Holding, B., Phillips, I., Twigger, D., Watts, M. (1990). Research on students' conceptions in science: a bibliography. Children's Learning in Science Group. Leeds: The University of Leeds

Some hints on reviews and summaries

The present bibliography contains some 2000 quotations. Users who are not so familiar with the research area and who want to get access to it may be troubled by the large number of articles. In order to make these many articles easier to handle some hints on review articles and on other summarizing publications are given in the following. Please keep in mind that the following selection has been made from my point of view. Although I have endeavored to avoid onesidenesses, there may still be some omissions.

<u>(a) Reviews of the research area</u>

Driver, R., Erickson, G. (1983). Theories-in-action: some theoretical and empirical issues in the study of students' conceptual frameworks in science. Studies in Science Education 10, 37 - 60

Gilbert, J., Watts, M. (1983). Concepts, misconceptions and alternative conceptions: changing perspectives in science education. Studies in Science Education 10, 61 - 98

Hashweh, M. (1986). Towards an explanation of conceptual change. European Journal of Science Education 8, 129 - 289

Driver, R. (1989). Students' conceptions and the learning of science. International Journal of Science Education 11, 481-490 (This is the introductory article of a special issue of this journal on students' conceptions research.)

Duit, R. (in press). Students' conceptual frameworks-consequences for learning science. In: Glynn, S., Yeany, R., Britton, B. (Eds.): The psychology of learning science. Hillsdale: Erlbaum

<u>(b) Proceedings of conferences</u>

Proceedings of the main conferences provide very valuable insights into research if papers are printed in full length. This is the case with the proceedings already mentioned above (Archenhold et al, 1980; Helm, Novak, 1983; Novak, 1987). At the same time these proceedings appear to mirror the development of the research area quite appropriately. Further proceedings are:

Duit, R., Säljö, Eds. (1988). Students' conceptions of subject matter content. Proceedings of a Symposium at the 2. European Conference on Learning and Instruction, Tübingen, Sept. 1987. Kiel: IPN Reports-in-Brief

Adey, P., Ed. (1989). Adolescent development and school science. London: Falmer Press

<u>(c) Books</u>

There are some books available in which the main approaches and results are summarized.

In Germany the following volume provided frameworks for planning research in our field:

Duit, R., Jung, W., Pfundt, H., Eds. (1981). Alltagsvorstellungen und naturwissenschaftlicher Unterricht. Köln: Aulis

A summary of research findings (mainly in the area of physics) as well as of main ideas of the research field has been worked out within a special issue of

a German teachers' journal:

Duit, R., Jung, W., Rhöneck, Ch. v., Eds. (1986). Alltagsvorstellungen - Energie - Elektrik - Optik - Mechanik - Wärme - Teilchen - Stoff. Naturwissenschaften im Unterricht - Physik/Chemie 34

In English the following book provides a summary of research findings in a couple of thematic areas (also mainly physics areas):

Driver, R., Guesne, E., Tiberghien, A., Eds. (1985). Children's' ideas in science. Milton Keyne: Open University Press

A somewhat more general overview is provided by:

Osborne, R., Freyberg, P., Eds. (1985). Learning in Science. The implication of children's science. Auckland, London: Heinemann

A Special Issue of the International Journal of Science Education (December 1989) provides an overview of approaches and research findings (see the introductory article of Driver mentioned above in section (a)).

In French the following book based on research results is available:

Giordan, A., Vecchi, G. de (1987). Les origines du savoir. Neuchatel, Paris: Delachaux & Niestle

(d) Summaries of research results on conceptions in thematic areas

Teachers, textbook authors and other developers of teaching and learning materials will be interested in students' conceptions in specific thematic areas (e.g. electric circuit, combustion, chemical reactions, genetics). The subdivisions of g6 in the present bibliography facilitate access to articles of interest. In a couple of areas summaries are available.

The above mentioned (s. (c)) issue of a German journal "Alltagsvorstellungen" provides summaries of students' notions on energy, electricity, optics, mechanics (especially force and movement), heat and particle model. In the book by Driver et al. also mentioned above (s. (c)) there are summaries of the areas of light, electricity, heat, mechanics (force and movement), particle model and astronomy. Another very valuable summary of conceptions in the area of mechanics is provided by:

McDermott, L. (1984). Research and conceptual understanding in mechanics. Physics Today, July 1984, 24 - 32

In German a summary of the same area is contained in:

Schecker, H. (1985). Das Schülerverständnis zur Mechanik. Dissertation Universität Bremen

On electricity a conference was held in 1984. The proceedings provide a summary of this area:

Duit, R., Jung, W., Rhöneck, Ch. v., Eds. (1985). Aspects of understanding electricity. Kiel: IPN

Concerning the particle model there are also proceedings of a conference available that summarize the state of the art in this area:

Lijnse, P.L., Licht, P., de Vos, W., Waarlo, A.J., Eds. (1990). Relating macroscopic phenomena to microscopic particles. Utrecht: The University of Utrecht, Centre for Science and Mathematics Education

Summaries of thematic areas of chemistry and biology do not appear to be available so far. Of course, the latest papers on a thematic area usually try to summarize findings of preceding studies. To gain access to such articles the subdivisions "g6, C" and "g6, B" will help.

(3) REMARKS ON TRENDS IN THE RESEARCH AREA "STUDENTS' CONCEPTIONS AND SCIENCE EDUCATION"

Overviews

Tables 1 and 2 provide some figures on the state and development of the research field. The figures in tab. 1 indicate the number of articles in the present bibliography in the groups g1 to g9 (as well as in some subgroups) that have been published at particular periods in time. From 1971 to 1990 periods of four years have been chosen. It becomes visible in tab. 1 that the present boom of research in the field started in the middle of the 70s and continues until the present. The largest number of articles (about 50%) have fallen into group g6 (i.e. they deal with investigations of students' conceptions on the content level). Most dominant is the area of physics. It is only since the beginning of the 80s that a considerable number of studies on newly developed learning and teaching approaches have been published (see the line of g7 in tab. 1). Tab. 1 further shows that there is another interesting trend towards a

more general view of conceptions that started in the middle of the 80s. Only since then has there also been a considerable number of studies on teachers' conceptions (g8), on consequences for teacher training (g9), on students' and teachers' conceptions of the learning process (CTL) and on the range and nature of science knowledge (CSC).

	<1960	60-70	71-74	75-78	79-82	83-86	87-90	total
g1	9	5	19	45	91	154	165	668
g2	-	2	1	2	3	8	5	21
g3	-	-	4	3	3	14	16	40
g4	6	17	11	12	14	18	19	97
g5	2	1	5	10	53	74	86	231
g6	36	38	38	79	210	365	355	1121
g6,P	8	15	19	41	129	262	239	713
g6,C	3	2	5	8	23	28	58	127
g6,B	10	8	12	13	21	68	64	196
g7	-	7	6	13	26	115	156	323
g7,P	-	-	1	10	16	70	107	204
g7,C	-	5	-	3	1	2	15	26
g7,B	-	-	1	1	4	13	17	36
g8	3	-	-	-	2	11	53	66
g9	-	-	-	-	-	2	27	29
g1 to g9	47	69	82	150	339	596	708	1991

Table 1
Number of articles in groups g1 to g9 - at particular intervals of time.
The column "total" presents the total number of articles in a group

Mechanics	281	Force and motion/work,power,energy/speed, acceleration/gravity/pressure/density/ floating,sinking
Electricity	146	Simple,branched circuits/topological and geometrical structure/models of current flow/current,voltage,resistance/electro-statics/electromagnetism/danger of electricity
Heat	68	Heat and temperature/heat transfer/expansion by heating/change of state,boiling, freezing/explanation of heat phenomena in the particle model
Optics	69	Light/light propagation/vision/ color
Particles	60	Structure of matter/explanation of phenomena(e.g.heat,states of matter)/conceptions of the atom/radioactivity
Energy	69	Energy transformation/ energy conservation/ energy degradation
Astronomy	36	Shape of the earth/characteristics of gravitational attraction/satellites
"Modern" Physics	11	Quantum physics/special relativity
Chemistry	132	Combustion,oxidation/chemical reactions/ transformation of substances/chemical equilibrium/symbols,formula/mole concept
Biology	208	Plant nutrition/photosynthesis/osmosis/ life/origin of life/evolution/human circulatory system/genetics/health/growth

Table 2: Studies on Students' Conceptions in Different Areas (the figures give the number of articles contained in the present edition of the bibliography in a certain area)

Table 2 portrays investigations of students' conceptions on the content level (g6). The dominance of studies in the area of physics also becomes visible here, but it is also interesting that even in physics there are many topics of school physics where nothing or nearly nothing is known about students' conceptions. It might not be too surprising that the number of articles on modern physics is so low (only 11 articles), but it is remarkable that the

number of studies on common topics such as magnetism or sound is very small. There is therefore still a need for further studies on students' conceptions on the content level. This is not only true for biology and chemistry but also for physics. Tab. 2 and the lists of articles in g6 may help to identify deficient fields.

On the many labels used to indicate students' notions

Many labels are used to indicate what is called students' notions, students' conceptions or students' alternative frameworks in this bibliography (e. g. misconceptions, students' science, mini theories, belief systems). The most "neutral" terms appear to be students' conceptions and students' notions, simply indicating mental representations of the outside world. The label "alternative framework" used in the title of the bibliography stands for a program accepted by the overwhelming majority of researchers in our field. This is a program which views students' conceptions as conceptions in their own right and not as false ideas which have to be erased as fast as possible (quite often the label misconception indicates the latter position). The labels used therefore stand for somewhat different or considerably different positions (see the overview in Duit, 1987, g1; p. 8). They are embedded in different theoretical frameworks. The large number of labels used therefore indicates that manifold theoretical approaches are employed in the research area. So far, no "unifying" theory appears to be in sight.

Of course, there is much concurrence among the manifold theoretical approaches despite the differences. The unifying basic idea is the following view of the learning process. Learning is <u>not</u> viewed as a passive taking over (filling in) of knowledge. Learning is viewed as a very active process. It is a process in which the learner has to construct actively his/her knowledge on the basis of the conceptions already present in the cognitive structure. These pre-conceptions play a decisive role in the learning process. They guide interpretation of sense impressions and the process of planting new pieces into the already existing cognitive structure. This constructivistic view of learning has become the common denominator of research in the field documented in the present bibliography.

Why did the research area start in the middle of the 1970s and grow so rapidly?

The "active" constructivistic view of learning we have just sketched is by no means a new one. It can be traced back far into the history of pedagogy and science instruction (see a German perspective in Jung, 1984, gl; p. 18). Since the beginning of the 20th century there have not only been thoughts in accordance with the "active" view but also empirical studies on students' conceptions of science phenomena. Of course, Piagets' seminal work must be mentioned here. But there are many other "early" studies too (see e.g. the review of Oakes, 1947, gl, p. 25).

Since the middle of the 1970s there has been a boom of research on students' conceptions in science – mainly in the "western" world. The start and the rapid growth of research appears to be due to the fact that the interests of science educators and cognitive psychologists met. On the one hand science educators were not too pleased with the outcomes of the curriculum movement in the 1960s and early 1970s. Despite many efforts (e.g. new experiments, new curriculum materials) and orientation to the structures of the disciplines students still had severe difficulties in learning science concepts and theories. The new curricula were not as successful as expected in guiding students from their (everyday) conceptions to those of science. Science educators therefore felt a need to study the role of pre-conceptions in learning science conceptions in more detail.

On the other hand cognitive psychologists tried to overcome the behavioristic view of learning which had dominated so far. The behavioristic view was close to the above mentioned "passive" view. the new cognitive psychology was in accordance with the "active" view.

The interests of the two groups met insofar as they were both interested in the role of preconceptions. Science educators wanted to find out the main preconceptions which have to be regarded along the students' path to the science conceptions. Cognitive psychologists wanted to investigate the role of preconceptions in the process of learning and problem solving in a very general manner. Science topics (especially physics topics) turned out to be well suited for this purpose. In the beginning, the main emphasis of research was in "g6 Investigations of students' notions" according to the interests mentioned above.

Trend I: From studies on conceptions to studies on the impact of newly developed teaching materials and teaching strategies

As we mentioned above, studies on students' preconceptions and changes which have occurred in such preconceptions during instruction predominated at the start of the research area and still play an important role. But there is a growing number of studies which investigate the impact of new approaches to overcoming the difficulties indicated by the studies in "g6". This trend is clear if one compares the number of quotations in "g7, Instruction taking students' notions into account" in the past four year periods as in tab. 2.

Several different kinds of consequences are drawn in the approaches available. The most important ones appear to be the following:

- Content structure of instruction is changed, i. e. the set-up of content is altered in order to meet students' difficulties.
- New teaching materials (new textbooks, new experiments, new computer programs and etc.) are developed.
- New teaching strategies are developed (e. g. what are known as constructivistic strategies). Of course, among the strategies proposed some "old friends" (such as socratic dialogue) are to be found.
- Strategies of meta-learning are employed in order to guide students to a new view of their learning process (see below for more remarks on this).
- Teachers' view of learning and teaching is altered in order to guide teachers from the still predominating "passive" view to the "active" one.

Trend II: Investigations of students' conceptions of the nature and role of science and of students' views of their learning process

The "active" view of learning underlying research in our field highlights the importance of preconceptions. When research began there was a concentration on cognitive preconceptions on the content level (i. e. on conceptions such as light, the electric circuit, combustion, photosynthesis, animals). Meanwhile a broader perspective has been adopted. At first, science conceptions on a "meta-level", i. e. conceptions of the nature and role of science knowledge, are considered (see articles with the keyword CSC; see p. 209 ff). This mirrors the conviction that the way science is learned is considerably influenced by the students' view of what science is about. Secondly, the students' view of their

learning process is taken into consideration (see articles with the keyword CTL; see p. 205 ff). Research has shown that the view of learning influences learning considerably. A learner, for instance, who views learning as a process of filling in knowledge provided by the teacher or the textbook will learn accordingly, i. e. will adopt a "passive" learning habit. There is a further kind of "conception" dealt with by some studies now, namely students' interests and attitudes towards science and science instruction.

Another "enlargement" must be mentioned. Whereas students' conceptions were investigated almost exclusively at the beginning of the research area some 10 to 15 years ago, teachers' conceptions are now increasingly being taken into consideration (namely teachers' conceptions in a very broad sense, i. e. conceptions in specific content areas, conceptions of science and conceptions of teaching and learning).

The trend towards a broader investigation of conceptions appears to be the most important one in the research area. It is indeed a great challenge to research in our field. On the one hand, considering the entire complexity of school science learning is unavoidable, but on the other hand, research could lose its bearings in the labyrinth of this complexity.

Trend III: Theoretical approaches

Science educators in Germany who started research in the mid 1970s were quite aware that their work was part of a longstanding tradition, namely that of to start instruction with students' preinstructional knowledge, interests and attitudes. There will certainly be similar traditions in other countries. In some way Ausubel's work draws on these traditions. His dictum "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" was and still is accepted as motto by most researchers in our field.

It is interesting to look at Piaget's role in our research field because it is quite conflicting. On the one hand all researchers relied heavily upon Piaget. Without Piaget's theoretical ideas, his investigations in so many thematic fields and his method of investigation research would have followed quite different paths. On the other hand research on students' notions was quite often

deliberately distinct from Piaget. There was, for instance, in our research field a very general agreement that the contents of specific notions (such as notions of light, heat, burning) are of greater importance for learning processes in science than Piaget's general operations of thinking. Sometimes quite heavy battles were fought between "Piagetians" and "Alternative Frameworkers". But it appears that now most researchers take a more tolerant line, i. e. a position conceding that both general operations of thinking and conceptions (in the above mentioned broad sense) are important aspects in learning science. I think, by the way, that both "parties" have profited considerably from "fighting" one another.

It has been mentioned above that two "groups" started research in our field, namely science educators and cognitive psychologists. The latter group supplied the research field with their theories, e. g. network theories or information processing theories with the computer as paradigm for a learning system.

Without any doubt, the philosophy of science as developed by Hanson, T. S. Kuhn, Feyerabend and Lakatos influenced research considerably. In these approaches there was the idea of theory laden observation and the theory-guided development of learning.

The rapid growth of research on students' conceptions since the mid 1970s is, therefore, due at least in part to the fact that main lines of contemporary thinking were adopted and further developed. Not only the positions of philosophy of science were employed. Research was also implicitly influenced by contemporary science ideas which are known under headings such as self-organisation (in open systems). This is true because there are manifold relations of these lines of thinking with ideas of artificial intelligence which influenced research in our field via the already mentioned approaches of information processing theories. The rediscovery of constructivistic approaches fits in very well with the trend we have outlined. These approaches have considerably influenced research on students' conceptions.

Since the end of the 1970s such constructivistic ideas have been employed in our research field. In the interim many different approaches have found their way onto "the market", ranging from G. Kelly's theory of personal constructs to Vygotsky's approach of social constructivism. To employ such approaches has been quite fruitful. But it cannot be overlooked that the word constructivism (or constructivistic) is sometimes used merely as another label for what has

been referred to as the "active" view of learning above. Such a renaming appears to be of very limited use for the progress of research.

BIBLIOGRAPHIE
Dieser Teil der Bibliographie enthält etwa 2000 Artikel, die bis September 1990 aufgenommen worden sind.

BIBLIOGRAPHY
This part of the bibliography contains some 2000 articles entered before September 1990.

g1 ZUM UMFELD DES PROBLEMS "VORSTELLUNGEN DER SCHÜLER" GENERAL CONSIDERATIONNS CONCERNING RESEARCH IN THIS AREA

Abimbola, I.O. (1988). The problem of terminology in the study of student conceptions in science. Science Education 72, 175-184
g1

Adey, P. (1987). A response to "Towards a Lakatosian analysis of Piagetian and alternative conceptions research programm". Science Education 71, 1, 5-7
g1

Adey, P., Shayer, M. (1988). Strategies for meta-learning in physics. Physics Education 23, 97-104
g1

Aebli, H. (1963). Über die geistige Entwicklung des Kindes. Stuttgart: Klett
g1

Aebli, H. (1970). Piaget and beyond. Interchange 1, 12-24
g1

Aebli, H. (1977). Piagets Deutung der kognitiven Entwicklung und ein Gegenmodell des geleiteten Strukturaufbaus. In: Reulecke, H.: Strukturelles Lernen. Hamburg: Hoffmann und Campe, 145-161
g1

Aissen-Crewett, M. (1990). Alltagserfahrung und experimentell-empirische Erfahrung. In: Wiebel, K.H.: Zur Didaktik der Physik und Chemie: Probleme und Perspektiven. Vorträge auf der Tagung für Didaktik der Physik/Chemie in Kassel, September 1989. Alsbach: Leuchtturm, 362-364
g1

Albert, E. (1979). Can Ausubel's theorie of meaningful learning become an alternative to Piagetian psychology ? Science Education 63, 1, 135-138
g1

Allen, R.D., Donovan, M.P., Statkiewicz, W.R. (1983). Student perceptions of evidence and interpretations. In: Helm, H., Novak, J.D.: Proceedings of the International Seminar "Misconceptions in Science and Mathematics". Ithaca, N.Y.: Cornell University, 79-83
g1

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E - Elektrizität	**- electricity**

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T - Wärme	- heat

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g6 UNTERSUCHUNGEN ZU VORSTELLUNGEN
INVESTIGATIONS OF NOTIONS

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g6,P,M

g6 UNTERSUCHUNGEN ZU VORSTELLUNGEN INVESTIGATIONS OF NOTIONS	
P - Bereich der Physik	**Area of physics**
O - Optik	**- optics**

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g6,P,O
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g6,P,O,OCI

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g6,P,O,OCI

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g6,P,O,OCI

g6 UNTERSUCHUNGEN ZU VORSTELLUNGEN
INVESTIGATIONS OF NOTIONS

P - Bereich der Physik	**Area of physics**
AT - Atome / Teilchen	**- atoms / particles**

Andersson, B. (1990). Pupils' conceptions of matter and its transformations (age 12-16). Studies in Science Education 18, 53-85
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g5,g6,P,AT
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g6,P,AT
Bayer, H.J. (1986). Schülervorstellungen beim Übergang vom Bohrschen zum wellen-mechanischen Atommodell. In: Kuhn, W.: Didaktik der Physik. Vorträge auf der Physikertagung 1986 in Gießen. Gießen: DPG-Fachausschuß Didaktik der Physik, 249-256
g6,P,AT,Q
Benyamna, S. (1987). La pregnance du modele particulaire dans les representations d'etudiants en science, a l'egard de phenomenes naturels. Quebec: Universite Laval
g6,P,AT,O,E
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g1,g6,P,Q,AT,EN,CSC
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g6,P,AT
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g6,P,AT
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g6,C,P,M,AT
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g6,P,M,AT
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g6,P,AT,C

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g6,P,AT,C

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g6,P,AT

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g6,P,AT

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g6,P,M,AT,C

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g6,P,AT,C

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g6,P,AT

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g6,P,AT

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EN - Energie	- energy

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INSTRUCTION TAKING STUDENT'S NOTIONS INTO ACCOUNT	
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T - Wärme	**- heat**

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Sere, M.G., Weil-Barais, A. (1989). Physics education and students' development. In: Adey, P.: Adolescent development and school science. London: Falmer Press, 105-123
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Smith, C., Snir, J., Grosslight, L. (1987). Teaching for conceptual change using a computer-based modelling approach: The case of weight/density differentiation. Cambridge: Educational Technology Center
g7,P,M
Smith, C., Snir, J., Unger, C.M., Grosslight, L. (1990). Facilitating conceptual differentiation using conceptual models. Paper presented at the annual meeting of the American Educational Research Association, Boston MA
g7,P,M
Solomon, J. (1982). How children learn about energy or does the first law come first ? The School Science Review 63, 224, 415-422
g6,g7,P,M,EN,OCI
Solomon, J. (1983). Learning about energy: How pupils think in two domains. European Journal of Science Education 5, 1, 49-59
g6,g7,P,M,EN
Stepans, J., Dyche, S. (1987). Using the personal interview to determine student misunderstandings in science and some suggestions for alleviating those misunderstandings. In: Novak, J.: Proceedings of the 2. Int. Seminar Misconceptions and Educational Strategies in Science and Mathematics, Vol.I. Ithaca: Cornell University, 466-480
g6,g7,P,M,B
Stepans, J., Dyche, S., Beiswenger, R. (1988). The effect of two instructional models in bringing about a conceptual change in the understanding of science concepts by prospective elementary teachers. Science Education 72, 2, 185-195
g7,P,M
Terry, C., Jones, G. (1986). Alternative frameworks: Newton's third law and conceptual change. European Journal of Science Education 8, 3, 291-298
g6,g7,P,M
Thorley, N.R., Treagust, D.F. (1987). Conflict within dyadic interactions as a stimulant for conceptual change in physics. International Journal of Science Education 9, 2, 203-216
g6,g7,P,M,E
Ueno, N., Arimoto, N., Fujita, G. (1990). Conceptual models and points of view - Learning via making a new stage. Paper presented at annual meeting of the American Educational Research Association, Boston
g7,P,M
van den Berg, J., Raat, J. (1985). Problem solving in mechanics - An experiment in mechanics teaching. In: Lijnse, P.L.: The many faces of teaching and learning mechanics. Conference on physics education. Utrecht: GIREP/SVO/UNESCO, 329-335
g6,g7,P,M
Van Hise, Y.A. (1988). Student misconceptions in mechanics: An international problem ? The Physics Teacher 26, 11, 498-502
g6,g7,P,M

van't Hul, F.E., van Joolingen, W.R., Lijnse, P.L. (1989). Begripsverandering en microcomputers, praktijkervaringen met kracht en beweging. Tijdschrift voor Didactiek der β-wetenschappen 7, 3, 172-191
g7,P,M

White, B. (1984). Designing computer games to help physics students understand Newton's laws of motion. Cognition and Instruction 1, 1, 69-108
g7,P,M

Zietsman, A.I., Clement, J. (1990). Using anchoring conceptions and analogies to teach about levers. Paper presented at the annual meeting of the American Educational Research Association, Boston MA
g7,P,M,OCI

Zietsman, A.I., Hewson, P.W. (1986). Effect of instruction using microcomputer simulations and conceptual change strategies on science learning. Journal of Research in Science Teaching 23, 1, 27-39
g7,P,M

g7 UNTERRICHT UNTER BERÜCKSICHTIGUNG VON VORSTELLUNGEN DER SCHÜLER	
INSTRUCTION TAKING STUDENT'S NOTIONS INTO ACCOUNT	
P - Bereich der Physik	**Area of physics**
O - Optik	**- optics**

Anderson, C.W., Smith, E.L. (1983). Children's conceptions of light and color: Understanding the concept of unseen rays. East Lansing: Michigan State University
g6,g7,P,O
Anderson, C.W., Smith, E.L. (1984). Children's preconceptions and content-area textbooks. In: Duffy, G., Roehler, L.R., Mason, J.: Comprehension instruction: Perspectives and suggestions. New York: Longman, 187-201
g6,g7,P,O,B
Bouwens, R.E.A., Verkerk, G. (1989). De inrichting van een optica-curriculum, uitgaande van misconcepties. Tijdschrift voor Didactiek der β-wetenschappen 7, 1, 27-44
g7,P,O
Claus, J., Stork, E., Wiesner, H. (1982). Optik im Sachunterricht. Eine empirische Untersuchung zu Vorstellungen und Lernprozessen. Sachunterricht und Mathematik in der Primarstufe 10, 82-92
g6,g7,P,O
Eaton, J.F., Anderson, C.W., Smith, E.L. (1984). Students' misconceptions interfere with science learning: Case studies of fifth-grade students. The Elementary School Journal 84, 4, 365-379
g6,g7,P,O
Engelhardt, P., Wiesner, H. (1985). Bericht über eine Einführung in die Optik in einer 7. Klasse. In: Kuhn, W.: Didaktik der Physik. Vorträge auf der Physikertagung 1985. München: DPG Fachausschuß Didaktik der Physik, 239-243
g7,P,O
Feher, E. (1990). Interactive museum exhibits as tools for learning: explorations with light. International Journal of Science Education 12, 1, 35-49
g5,g7,P,O
Feher, E., Rice, K. (1986). Shadow. Science and Children
g7,P,O
Fetherstonhaugh, A.R. (1988). Students' understanding of light: Can teaching for conceptual change lower the level of misconception ? Perth, Western Australia: Curtin University of Technology
g5,g6,g7,P,O,OCI
Fetherstonhaugh, A.R., Happs, J.C. (1988). Countering fundamental misconceptions about light. An analysis of specific teaching strategies with year 8 students. Research in Science Education 18, 211-219
g6,g7,P,O,OCI
Fetherstonhaugh, T., Treagust, D.F. (1990). Students' understanding of light and its properties following a teaching strategy to engender conceptual change. Paper presented at the Special Interest Group on Subject Matter Knowledge and Conceptual Change of the annual meeting of the A.E.R.A., Boston, MA, 16-20 April 1990
g6,g7,P,O

Goldberg, F. (1987). Using an interactive videodisc as a tool for investigating and facilitating student understanding in geometrical optics. In: Novak, J.: Proceedings of the 2. Int. Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol.III. Ithaca: Cornell University, 180-186
g7,P,O

Goldberg, F.M., McDermott, L.C. (1986). Student difficulties in understanding image formation by a plane mirror. The Physics Teacher 24, 8, 472-480
g6,g7,P,O

Guesne, E. (1985). Light. In: Driver, R., Guesne, E., Tiberghien, A.: Children's ideas in science. Milton Keynes: Open University Press, 10-33
g6,g7,P,O

Hoffmann, K., Wiesner, H. (1982). Lassen sich Alltagsvorstellungen über optische Phänomene durch Unterricht wirksam korrigieren ? physica didactica 9, 299-317
g6,g7,P,O

Hoffmann, K., Wiesner, H. (1984). Ein subjektivistischer Zugang zur Optik in der Sekundarstufe I. Bericht über einen Unterrichtsversuch zur Vermittlung der Sender-Empfänger-Vorstellung. Naturwissenschaften im Unterricht - Physik/Chemie 32, 7-11
g5,g7,P,O

Reiner, M., Finegold, M. (1987). Changing students' explanatory frameworks concerning the nature of light using real time computer analysis of laboratory experiments and computerized explanatory simulations of e.m. radiation. In: Novak, J.: Proceedings of the 2. Int. Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol.II. Ithaca: Cornell University, 368-377
g7,P,O

Solomon, J. (1989). Social influence or cognitive growth. In: Adey, P.: Adolescent development and school science. London: Falmer Press, 195-199
g1,g7,P,E,O

g7 UNTERRICHT UNTER BERÜCKSICHTIGUNG VON VORSTELLUNGEN DER SCHÜLER INSTRUCTION TAKING STUDENT'S NOTIONS INTO ACCOUNT

P - Bereich der Physik AT - Atome / Teilchen	Area of physics - atoms / particles

Andersson, B. (1990). Pupils' conceptions of matter and its transformations (age 12-16). Studies in Science Education 18, 53-85
g6,g7,P,AT,C

Berkheimer, G.D., Anderson, C.W., Spees, S.T. (1988). Using conceptual change research to reason about curriculum. East Lansing: Michigan State University
g6,g7,P,AT

Dierks, W. (1989). An approach to the educational problem of introducing the discontinuum concept in secondary chemistry teaching and an attempted solution. Paper submitted to the international seminar on "Relating Macroscopic Phenomena to Microscopic Particles", Utrecht
g7,C,P,AT

Jung, W. (1971). Zur Behandlung der Atomphysik in der Sekundarstufe. Naturwissenschaften im Unterricht - Physik/Chemie 19, 1-8
g7,P,AT

Marcus, W., Pfundt, H. (1975). Die Entwicklung und Erhärtung der Hypothese vom diskontinuierlichen Aufbau der Stoffe. Der mathemt .ische und naturwissenschaftliche Unterricht 28, 8, 472-477
g7,C,P,AT

Nussbaum, J. (1985). The particulare nature of matter in the gaseous phase. In: Driver, R., Guesne, E., Tiberghien, A.: Children's ideas in science. Milton Keynes: Open University Press
g6,g7,P,AT

Nussbaum, J., Novick, S. (1982). Alternative frameworks, conceptual conflict and accommodation: Toward a principled teaching strategy. Instructional Science 11, 183-200
g7,P,AT

Osborne, R., Schollum, B. (1983). Coping in chemistry. The Australian Science Teachers Journal 29, 1, 13-24
g6,g7,P,AT,C,OCI

Pfundt, H. (1978). Zur Einführung der Atomhypothese. In: Weninger, J., Pfundt, H.: Atommodelle im naturwissenschaftlichen Unterricht, Band 2. Weinheim: Beltz, 10-24
g7,C,P,AT

Schollum, B., Osborne, R.J. (1985). Relating the new to the familiar. In: Osborne, R., Freyberg, P.: Learning in science. The implications of children's science. Auckland: Heinemann, 51-65
g6,g7,P,AT

Scott, P. (1987). The process of conceptual change in science: a case study of the development of a secondary pupil's ideas relating to matter. In: Novak, J.: Proceedings of the 2. Int. Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol.II. Ithaca: Cornell University, 404-419
g6,g7,P,AT

Simpson, M., Arnold, B. (1984). Diagnosis in action. Aberdeen: Aberdeen College of Education
g6,g7,P,EN,AT,B

Wightman, T., Green, P., Scott, P. (1986). Children's learning in science project. The construction of meaning and conceptual change in classroom settings: Case studies on the particulate nature of matter. Leeds: University of Leeds, Centre for Studies in Science and Mathematics Education
g6,g7,P,AT

g7 UNTERRICHT UNTER BERÜCKSICHTIGUNG VON VORSTELLUNGEN DER SCHÜLER INSTRUCTION TAKING STUDENT'S NOTIONS INTO ACCOUNT	
P - Bereich der Physik	**Area of physics**
AS - Astronomie	**- astronomy**

Nussbaum, J. (1985). The earth as a cosmic body. In: Driver, R., Guesne, E., Tiberghien, A.: Children's ideas in science. Milton Keynes: Open University Press
g6,g7,P,AS,OCI

Nussbaum, J., Sharodini-Dagan, N. (1983). Changes in second grade children's preconceptions about the earth as a cosmic body resulting from a short series of audio-tutorial lessons. Science Education 67, 99-114
g6,g7,P,AS

Sneider, C., Pulos, S., Freenor, E., Porter, J., Templeton, B. (1986). Understanding the earth's shape and gravity. Learning 14, 6, 43-47
g7,P,AS

Targan, D.S. (1987). A study of conceptual change in the content domain of the lunary phase . In: Novak, J.: Proceedings of the 2. Int. Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol.II. Ithaca: Cornell University, 499-511
g6,g7,P,AS

Treagust, D.F. (1987). An approach for helping students and teachers diagnose misconceptions in specific science content areas. In: Novak, J.: Proceedings of the 2. Int. Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol.II. Ithaca: Cornell University, 512-522
g5,g6,g7,P,C,B,AS

Vosniadou, S., Brewer, W.F. (1989). Mental models of the earth: A study of conceptual change in childhood. University of Illinois: Center for the Study of Reading
g6,g7,P,AS,OCI

g7 UNTERRICHT UNTER BERÜCKSICHTIGUNG VON VORSTELLUNGEN DER SCHÜLER INSTRUCTION TAKING STUDENT'S NOTIONS INTO ACCOUNT	
P - Bereich der Physik EN - Energie	Area of physics - energy

Alanach, D., Anderson, M., Brook, A., Davidson, J., Dow, A., Driver, R., Gater, S., Hughes, D., Kent, D., Powell, D., Price, B., Wells, P. (1987). Approaches to teaching energy. Leeds: Centre for Studies in Science and Math. Education/University of Leeds
g7,P,EN

Black, P., Solomon, J. (1983). Life world and science world: Pupils' ideas about energy. In: Marx, G.: Entropy in the school. Proceedings of the 6th. Danube Seminar on Physics Education. Budapest: Roland Eötvös Physical Society, 43-55
g6,g7,P,EN,ENT

Brook, A.J. (1987). Designing experiences to take account of the development of children's ideas: an example from the teaching and learning of energy. In: Novak, J.: Proceedings of the 2. Int. Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol.II. Ithaca: Cornell University, 49-64
g7,P,EN

Brook, A.J., Wells, P. (1988). Conserving the circus ? - An alternative approach to teaching and learning about energy. Physics Education 23, 80-85
g7,P,EN

Carr, M., Kirkwood, V. (1988). Teaching and learning about energy in New Zealand Secondary School junior science classrooms. Physics Education 23, 86-91
g7,P,EN

Carr, M., Kirkwood, V., Newman, B. (1987). Energy in three New Zealand Secondary School junior science classrooms. Working Paper No.307, University of Waikato, Learning in Science Project, 1-19
g7,P,EN

Carr, M., Kirkwood, V., Newman, B., Birdwhistel, R. (1987). Energy in three New Zealand Secondary School junior science classrooms. Research in Science Education 17, 117-128
g6,g7,P,EN,OCI

Griffiths, A.K., Thomey, K., Cooke, B., Normore, G. (1988). Remediation of student-specific misconceptions relating to three science concepts. Journal of Research in Science Teaching 25, 9, 709-719
g7,P,EN,C,B

Jung, W., Weber, E., Wiesner, H. (1978). Ein Versuch zur Einführung des Energiebegriffs. Der Physikunterricht 12, 2, 22-41
g7,P,M,EN

Kirkwood, V., Carr, M. (1988). "A most valuable growing exercise". A report on the interaction of teachers with the action-research phase. Research in Science Education 18, 95-103
g7,g9,P,EN

Kirkwood, V., Carr, M. (1988). Final Report: Learning in Science Project. Working paper (final report) of the Science Education Research Unit,University of Waikato, Hamilton N.Z.
g7,P,EN

Kirkwood, V., Carr, M. (1989). A valuable teaching approach: some insights from LISP (Energy). Physics Education 24, 332-334
g7,P,EN
Kirkwood, V., Carr, M., Bell, B., McChesney, ., Osborne, R., Symington, D. (1986). LISP (Energy): The strategy and some preliminary findings. Hamilton, N.Z.: University of Waikato
g7,g8,P,EN
Kirkwood, V., Carr, M., Gibb, S. (1986). Energy in New Zealand Secondary School junior science classroom, case study A. Working Paper No.304, University of Waikato, Learning in Science Project, 1-130
g7,P,EN
Kirkwood, V., Carr, M., Gibb, S., Shaw, J., Stonyer, J. (1988). Energy in New Zealand Secondary School junior science classrooms - Action research of a trial unit. Working paper (No.309) of the Science Education Research Unit, University of Waikato, Hamilton N.Z.
g7,P,EN,OIM,OCI
Kirkwood, V., Carr, M., Gibb, S., Shaw, J., Stonyer, J. (1988). Teachers' interactions with LISP (energy) research . Working paper (No.310) of the Science Education Research Unit, University of Waikato, Hamilton N.Z.
g7,g8,EN,P,CTL,CSC
Kirkwood, V., Carr, M., Newman, B. (1988). Energy in New Zealand Secondary School junior science classrooms - a trial unit. Working paper (No.308) of the Learning in Science Project, Science Education Research Unit, University of Waikato, Hamilton N.Z.
g7,P,EN,OCI,GEN
Kirkwood, V., Carr, M., Shaw, J. (1987). Energy in New Zealand Secondary School junior science classroom, case study C. Working Paper No.306, University of Waikato, Learning in Science Project, 1-115
g7,P,EN
Kirkwood, V., Carr, M., Stonyer, J. (1987). Energy in New Zealand Secondary School junior science classroom, case study B. Working Paper No.305, University of Waikato, Learning in Science Project, 1-153
g7,P,EN
Simpson, M., Arnold, B. (1984). Diagnosis in action. Aberdeen: Aberdeen College of Education
g6,g7,P,EN,AT,B
Solomon, J. (1982). How children learn about energy or does the first law come first ? The School Science Review 63, 224, 415-422
g6,g7,P,M,EN,OCI
Solomon, J. (1983). Learning about energy: How pupils think in two domains. European Journal of Science Education 5, 1, 49-59
g6,g7,P,M,EN
Solomon, J. (1985). Teaching the conservation of energy. Physics Education 20, 165-170
g6,g7,P,EN
Trumper, R. (1990). Energy and a constructivist way of teaching. Physics Education 25, 4, 208-212
g7,P,EN

g7	UNTERRICHT UNTER BERÜCKSICHTIGUNG VON VORSTELLUNGEN DER SCHÜLER INSTRUCTION TAKING STUDENT'S NOTIONS INTO ACCOUNT	
P	- Bereich der Physik - Sonstige	Area of physics - others

Arons, A.B. (1983). Students patterns of thinking and reasoning part 1. The Physics Teacher 21, 576-581
g7,P

Arons, A.B. (1984). Students patterns of thinking and reasoning part 2, part 3. The Physics Teacher 22, 21-26, 88-93
g7,P

Bethge, T. (1988). Empirische Untersuchungen über Schülervorstellungen zur Quantenphysik. In: Kuhn, W.: Didaktik der Physik. Vorträge der Physikertagung in Gießen. Gießen: DPG Fachausschuß Didaktik der Physik, 249-254
g7,P,Q

Ennenbach, W. (1983). The influence of model-instruction on "Conception- and Misconception-Learning" in biology and physics. In: Helm, H., Novak, J.D.: Proceedings of the International Seminar "Misconceptions in Science and Mathematics". Ithaca, N.Y.: Cornell University, 32-38
g7,B,P

Finegold, M., Reiner, M. (1985). Student learning behaviors as a means for a cognitive evaluation of a physics program. Studies in Educational Evaluation 11, 105-111
g7,P

Fischler, H., Lichtfeldt, M. (1990). Quantenphysik in der Schule II: Eine neue Konzeption und ihre Evaluation. physica didactica 17, 1, 33-50
g7,P,Q,OCI

Genin, C., Pellet, A., Michaud-Bonnet, J. (1987). Structuration mathematique des representations des eleves scientifiques a propos des grandeurs physiques vectorielle. In: Giordan, A., Martinand, J.L.: Modeles et simulation. Actes des 9. journees int. sur l'ed. scient. Chamonix: Centre Jean Franco, 112-116
g6,g7,P

Giordan, A., Vecchi, G. de (1987). Les origines du savoir. Neucha el,Paris: Delachaux & Niestle
g1,g3,g5,g6,g7,P,C,B

Lichtfeldt, M. (1989). Evaluation eines Unterrichtsentwurfes zur Einführung in die Quantenphysik. In: Kuhn, W.: Didaktik der Physik. Vorträge auf der Physikertagung 1989 in Bonn. Gießen: Deutsche Physikalische Gesellschaft, Fachausschuß Didaktik der Physik, 394-400
g6,g7,P,Q

Malony, D.P. (1984). Cognitive physics educational research - a bibliography. Creighton, Omaha: University of Craighton, Physics Department
g1,g6,g7,P

Mestre, J., Touger, J. (1989). Cognitive research - What's in it for physics teachers ? The Physics Teacher 27, 9 , 447-456
g1,g7,P

Niedderer, H., Schecker, H., Bethge, T. (1989). Computer-based modelling, student-centered teaching strategy and the development of physics concepts. Paper based upon the research and development project "Computers in Physics Education", University of Bremen, Federal Republic of Germany
g7,P

Vegting, P. (1980). Education based on a new concept of teaching in physics. In: Archenhold, W.F., Driver, R., Orton, A., Wood-Robinson, C.: Cognitive development research in science and mathematics. Proceedings of an international seminar. Leeds: University of Leeds, 320-327
g7,P

Wesley, W. (1987). Toward a cognitive physics course. In: Novak, J.: Proceedings of the 2. Int. Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol.III. Ithaca: Cornell University, 578-580
g7,P

g7 UNTERRICHT UNTER BERÜCKSICHTIGUNG VON VORSTELLUNGEN DER SCHÜLER
INSTRUCTION TAKING STUDENT'S NOTIONS INTO ACCOUNT

C - Bereich der Chemie Area of chemistry

Allen, J. (1990). Effects of concept mapping on meaningful learning and achievement in secondary chemistry. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Atlanta
g7,C

Andersson, B. (1990). Pupils' conceptions of matter and its transformations (age 12-16). Studies in Science Education 18, 53-85
g6,g7,P,AT,C

Cachapuz, A.F.C., Maskill, R. (1987). Detecting changes with the learning in the organization of knowledge: use of word association tests to follow the learning of collision theory. International Journa of Science Education 9, 4, 491-504
g5,g6,g7,C,P,T

Dierks, W. (1988). Wer bra cht wirklich auch das Mol auf dem Wege zum Symbol ? Naturwissenschaften im Unterricht - Physik/Chemie 36, 29-32
g7,C

Dierks, W. (1989). An approach to the educational problem of introducing the discontinuum concept in secondary chemistry teaching and an attempted solution. Paper submitted to the international seminar on "Relating Macroscopic Phenomena to Microscopic Particles". Utrecht
g7,C,P,AT

Feldsine, J.E. (1987). Distinguishing student misconceptions from alternative frameworks trough the construction of concept maps. In: Novak, J.: Proceedings of the 2. Int. Seminar Misconceptions and Educational Strategies in Science and Mathematics, Vol.I. Ithaca: Cornell University, 177-181
g6,g7,P,C,M

Garnett, P.J., Garnett, P.J., Treagust, D.F. (1990). Implications of research on students' understanding of electrochemistry for improving science curricula and classroom practice. International Journal of Science Education 12, 2, 147-156
g6,g7,C,OCI

Giordan, A., Vecchi, G. de (1987). Les origines du savoir. Neuchatel, Paris: Delachaux & Niestle
g1,g3,g5,g6,g7,P,C,B

Griffiths, A.K., Thomey, K., Cooke, B., Normore, G. (1988). Remediation of student-specific misconceptions relating to three science concepts. Journal of Research in Science Teaching 25, 9, 709-719
g7,P,EN,C,B

Hammer, H.D. (1990). Hinführung zur Gibbs-Helmholtz-Beziehung aus Alltagserfahrungen und Alltagsvorstellungen zum Verständnis der Richtung von Prozessen. In: Wiebel, K.H.: Zur Didaktik der Physik und Chemie: Probleme und Perspektiven. Vorträge auf der Tagung für Didaktik der Physik/Chemie in Kassel, September 1989. Alsbach: Leuchtturm, 302-304
g7,C

Hand, B.M. (1988). Is conceptual conflict a viable teaching strategy ?: The students' viewpoint. The Australian Science Teachers Journal 34, 4, 22-26
g7,C

Hand, B.M., Treagust, D.F. (1988). Application of a conceptual conflict teaching strategy to enhance student learning of acids and bases. Research in Science Education 18, 53-63
g7,C
Herron, J.D. (1984). Using research in chemical education to improve my teaching. Journal of Chemical Education 61, 10, 850-854
g7,C
Hesse, J.J., Anderson, C.W. (1990). A case study of conceptual change teaching: Teaching the necessity of conservation in physical and chemical changes. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Atlanta
g7,g8,C,OCI,CTL
Krause, H. (1962). Wie deuten Kinder chemische Vorgänge ? Westermanns Pädagogische Beiträge 14, 359-365
g7,C
Krause, H. (1964). Von der Luft und dem Feuer. Westermanns Pädagogische Beiträge 16, 10-19
g7,C
Krause, H. (1965). Die Verbrennung der Metalle. Westermanns Pädagogische Beiträge 17, 1-16
g7,C
Krause, H. (1966). Die Verbrennung der Kohle. Westermanns Pädagogische Beiträge 18, 1-12
g7,C
Krause, H. (1967). Die Verbrennung der Kerze. Westermanns Pädagogische Beiträge 19, 1-16
g7,C
Marcus, W., Pfundt, H. (1975). Die Entwicklung und Erhärtung der Hypothese vom diskontinuierlichen Aufbau der Stoffe. Der mathematische und naturwissenschaftliche Unterricht 28, 8, 472-477
g7,C,P,AT
Mellouk, B. (1987). Les fondements epistemologiques d'un manuel de science. Quebec: Universite Laval
g7,C
Osborne, R., Schollum, B. (1983). Coping in chemistry. The Australian Science Teachers Journal 29, 1, 13-24
g6,g7,P,AT,C,OCI
Pfundt, H. (1975). Ursprüngliche Erklärungen der Schüler für chemische Vorgänge. Der mathematische und naturwissenschaftliche Unterricht 28, 157-162
g7,C
Pfundt, H. (1978). Zur Einführung der Atomhypothese. In: Weninger, J., Pfundt, H.: Atommodelle im naturwissenschaftlichen Unterricht, Band 2. Weinheim: Beltz, 10-24
g7,C,P,AT
Treagust, D.F. (1987). An approach for helping students and teachers diagnose misconceptions in specific science content areas. In: Novak, J.: Proceedings of the 2. Int. Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol.II. Ithaca: Cornell University, 512-522
g5,g6,g7,P,C,B,AS
Voorde, H.H. ten (1980). Education based on a new concept of teaching in chemistry. In: Archenhold, W.F., Driver, R., Orton, A., Wood-Robinson, C.: Cognitive development research in science and mathematics. Proceedings of an international seminar. Leeds: University of Leeds, 310-319
g5,g7,C

g7 UNTERRICHT UNTER BERÜCKSICHTIGUNG VON VORSTELLUNGEN DER SCHÜLER
INSTRUCTION TAKING STUDENT'S NOTIONS INTO ACCOUNT

B - Bereich der Biologie   Area of biology

Anderson, C.W., Sheldon, T., Dubay, J. (1986). The effects of instruction of college non-majors' conceptions of respiration and photosynthesis. Paper presented at the annual meeting of American Educational Research Association, Chicago
g7,B

Anderson, C.W., Smith, E.L. (1984). Children's preconceptions and content-area textbooks. In: Duffy, G., Roehler, L.R., Mason, J.: Comprehension instruction: Perspectives and suggestions. New York: Longman, 187-201
g6,g7,P,O,B

Arnold, B., Simpson, M. (1982). Concept development and diagnostic testing - osmosis in "o" grade biology. Aberdeen: Aberdeen College of Education
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CSC UNTERSUCHUNGEN VON VORSTELLUNGEN ÜBER DIE "NATUR" DER WISSENSCHAFTEN
STUDIES INVESTIGATING CONCEPTIONS OF SCIENCE

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Jimenez Aleixandre, M.P., Fernandez Perez, J. (1987). Selection or adjustment ? Explanations of university biology students for natural selection problems. In: Novak, J.: Proceedings of the 2. Int. Seminar "Misconceptions and Educational Strategies in Science and Mathematics". Vol.II. Ithaca: Cornell University, 224-238
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g6,B,GEN

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g6,P,M,GEN

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Posner, G.J., Strike, K.A. (1989). The conceptual ecology of physics learning. A poster session for presentation at the annual meeting of the American Educational Research Association, San Francisco
g6,P,M,O,CTL,CSC,GEN

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g6,STS,GEN

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AUTORENVERZEICHNIS

Die Zahlen im folgenden Register weisen auf die Seiten hin, auf denen Artikel des betreffenden Autors genannt sind.

AUTHORS' INDEX

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ANHANG 1

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APPENDIX 1

In the following publications that have been added to the bibliography during the preparation of the present edition from October to December 1990 are listed in alphabetical order.

ANHANG 1

APPENDIX 1

Andersson, B. (1990). Pupils' conceptions of matter and its transformations (age 12-16). In: Lijnse, P.L., Licht, P., Vos, W. de, Waarlo, A.J.: Relating macroscopic phenomena to microscopic particles: a central problem in secondary science education. Utrecht: CD-β Press, 12-35
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ANHANG 2

Im Juli 1990 haben – wie an anderer Stelle bereits erwähnt – Kollegen aus Leeds eine Bibliographie herausgegeben, die der hier vorliegenden im Umfang und in den verwendeten Schlagworten ähnlich ist.
In der folgenden Liste erscheinen die Publikationen aus dieser Bibliographie, die in der vorliegenden nicht enthalte sind.
Diese Artikel sind nur zum Teil verschlagwortet worden.

APPENDIX 2

As has already been mentioned already in July 1990 colleagues in Leeds issued a bibliography that is comparable to the present one where numbers of articles contained and keywords used are concerned.
In the following the articles from the Leeds bibliography that are not contained in the present bibliography are listed. Due to lack of time not all of the articles have yet been given keywords.

Carmichael, P., Driver, R., Holding, B., Phillips, I., Twigger, D., Watts, M. (1990):
Research on students' conceptions in science – a bibliography.
Leeds: University of Leeds, Children's Learning in Science Research Group

Wenn Sie an dieser Bibliographie interessiert sind, so schreiben Sie bitte an:

If you are interested in this bibliography, please contact:

The Project Secretary
Children's Learning in Science Research Group
Centre for Studies in Science and Mathematics Education
The University of Leeds
Leeds LS29JT
U.K.

ANHANG 2

APPENDIX 2

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Liste aller Schlagwörter I / List of keywords I

	Schlagwörter für die Einteilung in Gruppen	Keywords for assigning to groups
g1	Zum Umfeld des Problems Vorstellungen der Schüler	General considerations concerning research in this area
g2	Alltagsvorstellungen und wissenschaftliche Vorstellungen	Everyday notions and scientific notions
g3	Geschichtliche und individuelle Entwicklung von Vorstellungen	Development of notions in the history of science as compared to development of notions in individuals
g4	Sprache und Vorstellungen	Language and notions
g5	Methoden zur Erfassung von Vorstellungen	Methods to investigate notions
g6	Untersuchungen zu Vorstellungen (von Schülern)	Investigations of (students') notions
g7	Unterricht unter Berücksichtigung von Vorstellungen	Instruction taking students' notions into account
g8	Untersuchungen zu Vorstellungen von Lehrern	Investigations of teachers' notions
g9	Vorstellungen und Lehrerbildung	Notions and teacher training

Liste aller Schlagwörter II / List of keywords II

	Weitere Schlagwörter für die Gruppen g6, g7 und g8	Further keywords for groups g6, g7 and g8
B C P	Biologie Chemie Physik	biology chemistry physics
AT AS E EN ENT FLD INF IRR MAG M O Q R S STAT T	- Atome und Teilchen - Astronomie - Elektrizität - Energie - Entropie - Feld - Information - Irreversibilität - Magnetismus - Mechanik - Optik - Quantenphysik - Relativistische Physik - Schall - Statistische Physik - Wärme (Therm. Physik)	- atoms and particles - astronomy - electricity - energy - entropy - field - information - irreversibility - magnetism - mechanics - optics - quantum physics - relativistic physics - sound - statistical physics - heat (thermal physics)
CTL CSC STS	- Vorstellungen des Lehr-, Lernprozesses - Vorstellungen zur "Natur der Wissenschaften - Vorstellungen zum Nutzen naturwissenschaftlicher Kenntnisse in Technik und Gesellschaft	- conceptions of teaching/learning - conceptions of science - conceptions of the use of science for technology and society
GEN	- Geschlechtsspezifische Unterschiede werden untersucht	- gender differences are investigated
OCI	- Der Beitrag enthält Originalzitate aus Interviews, Fragebögen und dergleichen	- The article contains original quotations from interviews, questionnaires and the like
OIM	- Der Beitrag enthält Originalzeichnungen der Befragten	- The article contains original drawings of students or teachers

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